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EVOLUTIONARY EPISTEMOLOGY, LANGUAGE AND CULTURE

A Non-Adaptationist, Systems Theoretical Approach

EDITED BY NATHALIE GONTIER, JEAN PAUL VAN BENDEGEM and DIEDERIK AERTS

Springer

EVOLUTIONARY EPISTEMOLOGY,
LANGUAGE AND CULTURE

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SERIES A: PHILOSOPHY AND METHODOLOGY
OF THE SOCIAL SCIENCES

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EVOLUTIONARY EPISTEMOLOGY, LANGUAGE AND CULTURE

A Non-Adaptationist, Systems Theoretical Approach

edited by

NATHALIE GONTIER
Vrije Universiteit Brussel, Belgium
Research Assistant of the Research Foundation Flanders

JEAN PAUL VAN BENDEGEM
Vrije Universiteit Brussel, Belgium

and

DIEDERIK AERTS
Vrije Universiteit Brussel, Belgium

Springer

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“[. . .] to he who has arrived, no satisfaction can be given, whereas he who is ‘in progress’ will always be grateful.”

Otto Neurath

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Preface by the editors

Evolutionary Epistemology, Language and Culture was the title and the theme of a conference held at the Vrije Universiteit Brussel, Brussels, Belgium, in May 2004. The conference was organized by the Centre for Logic and Philosophy of Science (http://www.vub.ac.be/CLWF) and the Leo Apostel Centre (http://www.vub.ac.be/CLEA).

For the first time in history, scholars working on language and culture from within an evolutionary epistemological framework, and thereby emphasizing complementary or deviating theories of the Modern Synthesis, were brought together. Of course there have been excellent conferences on evolutionary epistemology in the past, as well as numerous conferences on the topics of language and culture. However, until now these disciplines had not been brought together into one all-encompassing conference. Moreover, previously there never had been such stress on alternative and complementary theories of the Modern Synthesis.

As this volume will make clear and as did the conference itself, this specific inter- and transdisciplinary approach is one of the next crucial steps that needs to be taken, if we ever want to unravel the secrets of phenomena such as language and culture.

Evolutionary epistemology (EE), a term coined by Donald T. Campbell, is an academic discipline that grew out of naturalized philosophy and philosophy of science. For a long time, EE has been made equivalent to the sloganesque one-liner introduced by Michael Ruse, who stated that evolutionary epistemology is about taking Darwin seriously. By this he meant that whenever we seek to understand phenomena such as language, culture, science, human creativity, cognition, or indeed, all other phenomena of life, we need to use the theory of Natural Selection, as first introduced by Charles Darwin.

This scientific statement was of enormous import, for it defined for the first time very clearly what the goal of evolutionary epistemology is: it is about accepting that all of life's phenomena and behaviours, be they human or non-human, are the result of an evolutionary process, and, even more importantly, that we can understand and explain these phenomena by studying this evolutionary process.

This means that the primary goal of all the sciences and of all scientific thinking concerned with the study of living phenomena or the behaviours expressed by various organisms, is to find explanations for these phenomena and behaviours from within a naturalistic approach. And this in turn implies that we should not only implement evolutionary and biological thinking within human or exact sciences, but that we should also naturalize the methodologies used.

The biological sciences in general and more specifically, evolutionary thinking have progressed enormously over the past decades, making it quite clear that evolution is a phenomenon that can occur in many different ways, sometimes even different from natural selection. Today we know that natural selection and evolution are far from synonymous and that they do not explain isomorphic phenomena in the world.

'Taking Darwin seriously' is the way to go, but today the time has come to take alternative and complementary theories that developed after the Modern Synthesis, equally seriously, and, furthermore, to examine how language and culture can merit from these diverse disciplines.

At the EELC conference, Franz Wuketits, one of the leading figures within EE, made two important observations. The first remark was that within the last few years, it seemed as if EE had vanished from the scientific agenda: all the commotion the discipline had brought about when it was first launched in the mid-20th century, seemed to have been fading away, along with the discipline itself. Wuketits was quite right in adding that it would be an enormous loss for the scientific enterprise if the latter were to happen.

His second observation was that he was very happy to see that, with the EELC conference, the research topic was being put back on the scientific agenda, and he stressed that the theme should have emphasized even more the relevance of EE for the study of language*s* and culture*s*, in the plural.

These two points were very well taken, indeed, and we would like to add that EELC is very much about applying evolutionary epistemology to the study of languages and cultures, even more so, it is about bringing evolutionary epistemologie*s* to bear on languages and cultures, all written in the plural. For today, EE is a discipline that has many facets and, therefore, the time has come not only to take Darwin seriously, but to take the different evolutionary epistemologies seriously.

This book is the first attempt to reinstate EE as one of the top-five priorities of the scientific endeavour, and it is with great confidence that we say, that if we take evolutionary epistemology seriously—for the tremendous importance of this discipline is yet to be felt in varying disciplines—the scientific research fields of language and culture will flourish even more.

CHAPTER OUTLINE

In the introduction, **Nathalie Gontier** gives a general account of what evolutionary epistemology, language and culture is all about, providing a short historical overview of how evolutionary epistemology became a topic on the scientific agenda of epistemologists.

In the first part, she examines how, through the history of philosophy, the idea of a first philosophy that would explain how we can acquire, describe and explain knowledge was adhered to by different scholars. She then sets out to demonstrate how this idea of a first philosophy was overthrown by the naturalistic approach, first introduced by Quine. Gontier explains how, contrary to a sociology of science or post-modern thinking, evolutionary epistemology can give scientific explanations of how knowledge is acquired and how we can examine its validity, by accepting the very fact that knowledge itself is a biological product and that it hence needs to be explained from within evolutionary biology.

In the second part of the article, the author compares various universal evolutionary frameworks that are put forward by different scholars within EE. Here, Gontier distinguishes between traditional EE and new EE, where adherents of the former develop universal selectionist accounts. The former take an adaptationist point of departure, and hence emphasize the active role of the environment, while the latter subscribe to an organismic point of view, based more on system-theoretical approaches to evolution.

In the third part, she examines why anthropologists in general find a naturalistic approach to culture appalling. She then explains how the study of culture can nevertheless benefit from an evolutionary epistemological stance, without loosing the specificity of the subject matters.

Finally, Gontier hints at how evolutionary epistemology can be implemented in the study of language, its origin and evolution.

The book is divided into four parts, where different theories of evolutionary epistemology are first discussed on their own, and later implemented in language and culture. The contributions in the final part show how EE, implemented in language and/or culture can benefit from various modelling techniques. In the preparation of the book there was no attempt made to harmonize the varying views put forward and defended by the different authors. On the contrary, our main goal has been to demonstrate just how heterogynous the field of EE (and evolutionary studies in general) is. Indeed, this diversity of opinions is a property that we understand to be absolutely vital and necessary for the development of the discipline. Therefore, we have chosen to juxtapose these different views, and, hopefully, in the process encourage others to share our opinion that all these complementary and alternative views are equally important. Indeed, they could well cast new light upon old problems in an extremely relevant way.

PART 1: EVOLUTIONARY EPISTEMOLOGY

In the first part, different evolutionary epistemologies are analyzed and compared. Questions that are raised are whether EE always needs to be based on adaptationist accounts; how EE poses itself as a genuine alternative to essentialist thinking; whether EE differs from constructivist accounts; and whether the selection schemes that are proposed to be at work in different phenomena, such as the evolution of life, science or culture, have been successful in bringing about the abandonment of essentialist thinking.

Contrary to earlier versions of evolutionary epistemology, where adaptationists accounts are taken as starting point to develop these theories, **Franz Wuketits** explores the possibilities of a non-adaptationist approach within EE. Earlier versions understand organisms as passive elements that are or are not adapted to the environment. This view somehow gives the impression that organisms are passive objects, shaped by the active environment they live in. Wuketits refutes this idea, and pleads for the adoption of an organismic perspective in evolutionary thinking. Based upon the systems-theoretical approach, he argues that inner processes of internal selection, self-regulation and inner order need to be taken into account when examining an organism. And this idea, together with the fact that there is a constant interaction between an organism and its surroundings, makes Wuketits defend that adaptability (as opposed to adaptation) is not defined by the environment, but by the organism itself. This view also has serious epistemological consequences: instead of assuming that the perceiving apparatus of different organisms needs to correspond (in a realistic sense of the word) to the outer world, the author argues that this notion needs to be replaced by the notion of a functional coherence.

The contribution of **Alexander Riegler** is a highly ambitious undertaking. He considers on the one hand ‘evolutionary epistemology’ and, on the other, ‘radical constructivism’, proposing a theory to bridge the gap between the two approaches. He characterizes the former as an approach that focuses on external behaviour, while the latter emphasizes the perspective from within. This bridging attempt leads to a critical evaluation of the concept of hypothetical realism.

Olaf Diettrich searches for the biological boundary conditions for our classical physical world-view. He shows that the laws of nature are not objective properties of the world, rather they can be derived as invariants of human acting operators—from locomotion bringing about the classical conservation laws, as shown by Emmy Noether, up to the inborn cognitive operators bringing about the symmetries and regularities which constitute our classical world-view. Our organic phenotype, therefore, provides the boundary condition for our cognitive phenotype. Modern physical facilities that do not commute with the inborn operators require non-classical world-views.

Whether the real world is something more than the world of our experience is a question also raised by **Adrianna Wozniak**. Relations between Neo-Darwinism, transcendental philosophy and cognitive sciences are examined, and the nature of the phylogenetically acquired knowledge and the basic assumptions of evolutionary epistemology are analyzed. The speculations of constructivism and of subjective or transcendental idealism are criticized from the perspective of the suppositions of evolutionary epistemology. Finally, the ontological status of logic and mathematics are discussed from an evolutionary point of view.

We end the first part with **Derek Turner's** contribution. Contrary to the statement that Universal Darwinists undermine traditional essentialism, Turner argues that these scientists still adhere to a certain form of what he calls 'process essentialism' that, in essence, resembles Aristotelian thinking. After giving a general overview of the universal selection schemes as formulated by David Hull and Daniel Dennett, he examines how these selection principles are implemented in the study of science and culture. The basic idea, developed by Universal Darwinists is that phenomena like science and culture show an analogy regarding the specific kinds of evolutionary processes they can undergo, and this analogy, according to Turner, is based upon the idea that these similar evolutionary processes share essential features. Contrary to Universal Darwinists, the author proposes that we should not distinguish between accidental and essential properties of the evolutionary process, rather we should treat the different features of the evolutionary process as sharing a Wittgensteinian family resemblance.

PART 2: EVOLUTIONARY EPISTEMOLOGY AND LANGUAGE

The second part focuses on how evolutionary epistemology can be applied to language and vice versa. Questions raised include on the one hand, whether linguistics in itself suffices to understand language; and on the other hand the applicability of natural selection and modularity theory are being questioned and complemented with dynamical systems theories. The search for an adequate unit and level of selection is examined and authors ask whether it is fruitful or not to compare languages with biological species and/or organisms.

Mario Alinei forms a bridge with the first part, because he too questions essentialist thinking, as it applies to the field of linguistics. He attacks the mystifying view that language is a living organism, governed by an organic law. He sketches the historical setting that created this misunderstanding and in its stead he proposes a new theory—the 'Palaeolithic Continuity Theory (PCT)'—that holds that language is a social artefact with an interface with nature, governed by a law of conservation and only exceptionally prone to change. Furthermore he believes that PCT should be applicable to all cultural phenomena expressible in language, thereby making the connection with evolutionary epistemology.

The origin of language is re-examined from within the 'extended mind model', a theoretical framework developed by **Robert Logan**. He posits that language emerged to deal with the increasing complexity of hominid life. The author demonstrates how complexity theory and chaos theory can contribute to a better understanding of how language evolved. The emergence of language, according to Logan, represented a bifurcation from percept-based thinking to concept-based thinking. Our first concepts were our first words, which acted as strange attractors for all the percepts associated with these concepts.

Jean-Philippe Magué sets out to deal with the problem of the evolution of the lexicon in a changing environment. The basic metaphor, accredited to Salikoko Mufwene, is to see languages as species and idiolects as individuals. A multi-agent model is presented that models evolution of languages and is based upon the Roschian insights about categorization. A series of simulations shows the model at work demonstrating its strengths and shortcomings.

Besides the fact that we should take Darwin seriously, **Nathalie Gontier** pleads for an implementation of a universal symbiogenesis principle in the study of the origin and evolution of language. Therefore, she distinguishes between a vertical evolution concept, that is typical in Neo-Darwinian explanations of evolution by means of natural selection, and a horizontal evolution concept, characteristic of symbiogenesis, plant hybridization and the epidemiology of viruses. Gontier argues that the language-as-species metaphor is misleading in more than one way, because it essentializes language, making an abrupt distinction between the language-using-organisms and language itself, leaving scholars with the problem of combining these two element again. Finally, the author explores how a principle of universal symbiogenesis can be implemented in ideas about language variation and language change, language genes and conceptual blending.

Annemarie Peltzer-Karpf deals with past and present accounts of modularity in both neural and cognitive organizations. The discussion is placed within and against the framework of dynamic systems theory applied to the language acquisition of mono- and bilingual children. Data drawn from a large-scale long-term study of bilingual development in Turkish and Bosnian/Croatian/Serbian immigrant children provide evidence for the interplay of non-linear processes and the influence of environmental conditions on language and linguistic behaviour.

PART 3: EVOLUTIONARY EPISTEMOLOGY AND CULTURE

In the third part which focuses on how evolutionary epistemology can be implemented in culture, we again encounter criticisms directed towards essentialist thinking. This is most apparent in the nature/nurture debate on the one hand, and in the presumed dualistic interactions that occur between the organism and the environment on the other hand. The contributors of this part examine how we can overcome these dichotomous barriers. Based on alternative and complementary theories of the Modern Synthesis, all mainly inspired by system theoretical frameworks, the authors propose new levels and units of selection that are just as much present in the biological as in the cultural sphere.

A critical analysis of the concept 'human nature', is given by **Tim Ingold**, for he argues that this concept is a Western construal that impacts on a fundamental dichotomy at the heart of evolutionary thinking: namely the nature/culture divide. He argues that it is evolutionary science itself that continues this dichotomy, although researchers claim to do the contrary, because early hominids and even contemporary hunter-gatherers are conceived as standing at the crossroad between biological evolution on the one hand, and history and culture on the other. In his article, Ingold demonstrates that this dichotomous relationship is founded upon essentialist notions of 'human nature' and the author sets out to examine the presence of this notion in the biological species concept, ideas of a universal reason as defended by adherents of the doctrine of psychic unity, and within the idea of a genetic blueprint.

An extremely ambitious attempt to formulate a new framework for evolutionary epistemology, relying on Dynamic Systems Theory, is presented by **Eugenia Ramirez-Goicoechea**. Her goal is to consider a human being as a relational organism with its environment or, in other words, to emphasize the role of the sociocultural. Non-linearity, non-determinism and non-duality are core concepts in the formulation of this approach that also proposes a model for the re-creation and embodiment of knowledge from generation to generation.

Jean Lachapelle, Luc Faucher and Pierre Poirier revisit the Baldwin effect (the idea that learning can influence the rate and direction of evolution by natural selection). Inspired by a recent article from Godfrey-Smith, the authors propose a new, extended version of the Baldwin effect that leans on and incorporates the concept of 'niche construction'. Following Deacon's ideas on cultural niche construction, Lachapelle, Faucher and Poirrier then set out to demonstrate that the Baldwin effect, understood along these lines, played a fundamental role in the evolution and development of social norms.

Kathleen Coessens understands the evolutionary process that human beings underwent and their cultural creativity, as both depending on what she calls 'evolutionary flexibility'. Starting off with a phenomenological approach of the human body, Coessens then goes on to examine how evolutionary concepts such as adaptation, exaptation and affordances could bring about the possibility of introducing creative flexibility within evolutionary biology. Finally, she investigates how these forms of evolutionary flexibility at the biological level could lie at the basis of cultural creativity and vice versa, because she emphasizes that both processes are intertwined.

We end the third part with the contribution of **Hugo Mercier**. He takes on the challenging problem of explaining the status of mathematical knowledge from within an evolutionary epistemological framework. Usually the difficulty is to succeed in bringing about the transition from innate mathematical knowledge, modular or not, e.g., 'the number sense', to formal mathematics as we know it today. If Mercier's analysis holds good, it offers at the same time an explanation of the famous 'unreasonable effectiveness of mathematics'.

PART 4: EVOLUTIONARY EPISTEMOLOGY AND MODELLING

In the final part, we focus on how EE can be implemented in modelling techniques and vice versa. Modelling techniques as introduced by scholars working in Artificial Intelligence, Game Theory and even Quantum Mechanics, are today becoming part and parcel of scientific undertakings. Yet a lot of suspicions are being raised with respect to their value and helpfulness in examining, introducing and testing various theories. In this part, different academics working within different, sometimes non-neo-Darwinian fields, demonstrate how their theories can be used as well, and in so doing, they tackle some misunderstandings and confusions that are used to attack their models.

Bart de Boer gives us a general overview of how computer models can be used to investigate language evolution. He argues that language has extremely complex dynamics that can either be examined at the level of the individual, or at the level of a population. Systems with complex interactions have complex and difficult to predict dynamics, and computer simulations are, therefore, useful in studying them. The author presents three different techniques for building computer simulations on an accessible level: direct optimization, genetic algorithms and agent-based models and illustrates them with a number of examples. Finally, De Boer emphasizes the importance of correctly measuring and interpreting the results obtained from computer simulations, and shows how these models can be implemented in evolutionary epistemology and vice versa.

The view that linguistic conceptual domains are partly conventional and the result of a cultural evolution is the point of departure taken by **Joachim De Beule**. Contrary to the idea that language can be understood as a system of word-to-meaning mappings, he stresses the important role language users play in the conventionalization of language in order to solve the problem of efficient communication. He thereby focuses on the syntax and semantics of linguistic constructions about time. After examining how this conventionalization process takes place in natural languages, De Beule presents a computer model where a simulated population of autonomous language users evolve a shared ontology and language to communicate temporal information.

Ahti-Veikko Pietarinen discusses the distinction between semantic and pragmatic components of language from the game-theoretic point of view, and concludes that game-internal factors do not mark out the difference between what is semantic and what is pragmatic in language. He further provides an extension of game-theoretic semantics to evolutionary situations in order to capture not only the static meaning relations between language and the world but also semantic and pragmatic change.

The final article is contributed by **Diederik Aerts, Marek Czachor and Bart D'Hooghe**. The authors show that in human language rather unexpectedly genuine quantum structures manifest themselves. It leads the authors to reconsider the neo-Darwinian evolutionary scheme which they allege is too 'classical' in its conception, thus too limited to accommodate the quantum world. Moreover, they propose a novel way of looking at conceptual change, leading to new relations between biology and epistemology, EE in particular.

With this book we hope to make it clear to the reader that the specific combination of evolutionary epistemology, language and culture, is a very promising one. Indeed, for uni-directionally not only means that linguists and anthropologists should implement EE in their studies, but also that evolutionary epistemologists should focus even more than they have in the past, on the study of language and culture.

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First of all we wish to express our sincere gratitude towards all the participants of the EELC conference. Secondly, we are very much indebted to the contributors of this volume, because they have made the book what it is today. Thirdly, we want to thank our series-editor and the whole springer team very cordially for all their efforts.

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The editors,
Nathalie Gontier (Chair), Jean Paul Van Bendegem, Diederik Aerts
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Introduction to evolutionary epistemology, language and culture

Nathalie Gontier

Research Assistant of the Research Foundation–Flanders (F.W.O.- Vlaanderen)
Centre for Logic and Philosophy of Science,
Vrije Universiteit Brussel, Brussels, Belgium
nathalie.gontier@vub.ac.be

Abstract

Evolutionary epistemology (EE) is about developing a normative framework, based upon evolutionary thinking, that can explain all of an organism's phylogenetic and ontogenetic evolution. (1) EE is sketched as an inter- and transdisciplinary field that evolved out of naturalized epistemology as a reaction against logical empiricism and sociology of knowledge. (2) Different schools of evolutionary epistemological thinking are examined and compared. (3) It is argued that within EE today, the search for a normative evolutionary framework is narrowed down to the development of a framework based upon Neo-Darwinian theory. Because of this, other evolutionary theories that are very useful to explain certain phenomena are neglected. (4) These theories are briefly discussed. (5) It is shown how EE can be implemented in the scientific study of language and culture.

1. INTRODUCTION

Evolutionary epistemology (EE) is the most controversial, the most fascinating and the most difficult discipline within philosophy today. It is controversial because it declares all other philosophical disciplines bankrupt, and explains itself as part of the sciences. At the same time, it is a fascinating and difficult discipline because of its inter- and transdisciplinary character.

Philosophy can (amongst other distinctions) be divided into two domains: an *ontological* domain that examines what exists; and an *epistemological* domain that examines how we can gain knowledge of that what exists. EE obviously is part of the latter domain.

This article is divided into four parts. First, a brief historical sketch is given of how EE developed out of naturalized philosophies, the latter themselves being a reaction against empiricist and rationalist traditions. EE is a scientific discipline that evolved out of Quine's *Naturalized Philosophy* and adheres to the view that we can examine the knowledge-gaining-process from within

N. Gontier et al. (eds.), Evolutionary Epistemology, Language and Culture, 1–29.

evolutionary theory, because knowledge is a biological evolutionary product. Because EE involves a naturalistic and positivistic approach, it stands opposed to sociological frameworks of knowledge and post-modern thought.

In the second part of the article, different programmes that developed within EE are examined. EE does not only examine human knowledge-gaining-processes, it examines the knowledge-gaining-processes of all organisms while at the same time it also studies the products of these knowledge-gaining-processes, such as language, culture and science from within evolutionary biology.

The main goal of EE is to develop a *normative framework*, based upon and analogical to biological evolutionary thinking, that can explain not only all of *phylogenetic* evolution (the origin and evolution of species), but also *ontogenetic* evolution (the development of an organism from conception until death). This means, as will be demonstrated, that evolutionary theory is internalized, thereby raising questions about the *units* and *levels* of selection.

The normative frameworks that are being developed today, however, only make use of Neo-Darwinian theory and hence develop frameworks that are analogous to the evolution of genes by natural selection. Evolution is the phenomenon we want to explain; natural selection is only a theory that tries to explain this phenomenon. Evolution can occur in many different forms, and, therefore, it is necessary for us to broaden our perspective and look at other evolutionary theories as well, to see how these can enhance our understanding of language and culture. In the third and fourth part of the article, we, therefore, examine some peculiarities of languages and cultures and examine how EE can be implemented in the scientific disciplines that study language and culture.

2. PHILOSOPHY IS DEAD, LONG LIVE PHILOSOPHY!

> "In the middle of the 20th century, when it was realized that Bacon's New Atlantis had turned out to be Max Weber's Iron Cage, inhabited by Riesman's Lonely Crowd, and that the view that scientific theories have a partial observational interpretation by means of correspondence rules should never have become the Received View, philosophers started to move away from the long tradition of modernism, which had stretched from Bacon and Locke to the early Wittgenstein and to Carnap. Disillusioned with modernism, they turned a blind eye to the implications of biology and veered instead towards the post-modern relativism of Kuhn, the post-modern post-structuralism of Foucault, Derrida and Lyotard or to the post-modern pragmatism of Rorty and are showing unending and increasing interest in the obfuscations of Heidegger (Munz, 2001: vii)."

2.1. Empiricism/Rationalism

Within classical philosophy, there has always been the idea that we can found science upon something stronger than science itself: a first philosophy. Knowledge, according to this view, was perceived as a relation between a knower and something known (the rationalistic school, from which ideas about innateness developed) or something knowable (the empiricist school, from which ideas about nurture developed) (Munz, 2001: 28). This *something known* or *knowable* was the world in itself (*an sich*).

Rationalists and empiricists conceive of this knowledge relation as a direct relation: empiricists adhered to the view that they could perceive the world as it is, through their sense organs and that these senses somehow immediately were transformed into knowledge, knowledge that takes on the form of language; rationalists adhered to the view that men possessed innate ideas, that also took on the form of language, and that these ideas, because of a benign God, immediately gave direct knowledge of the world out there. There is an immediate correspondence between our words and the world in itself. So knowledge gained through the senses or through thinking, was correct knowledge.

People then, knew how the objective world out there was, and furthermore: this world was the precondition for all thinking and sensing. The knowers, therefore, were also interchangeable: they were conceived of as a-historical, unevolved or unchangeable individuals that were equipped with the same sense apparatus or with the same *universal* reason (see also Lorenz, 1987).

2.2. Hume and Kant

Two philosophical thinkers, David Hume and Immanuel Kant, put an end to this naïve realism. Hume (1985) stated that we can only trust knowledge that we receive from our senses. All knowledge that is not the result of, or that cannot be reduced to, our impressions,[1] is suspicious. Therefore, he distinguished between the world as we perceive it and the world as it is in itself. We do not have direct knowledge of the world out there and, therefore, we should not try to talk about that world, because we cannot make sense out of it. Hence, the knowledge relation becomes indirect. The generalizations we make regarding our incoming knowledge cannot be explained as being part of the world, but only as being part of our psychology. When we conclude that the sun will shine tomorrow, because she shined yesterday and the day before, and the

[1] Impressions in Hume's view are literally *im-pressions*, imprints from the world upon us. Locke's concept of *tabula rasa* is in order here: we are blank slates that are written upon by the world.

day before . . . we are not telling truths about the world, rather we are expressing our expectations towards that world, based upon previous experience. This, however, implies that we need to study human (psychological) nature, to make sense out of these statements.

Kant (1788, 1997) developed Hume's theories further, synthesizing them with rationalistic thought. We can only know the world as it appears to us, which differs from how we perceive it. Kant, therefore, introduced what he calls the Copernican turn in philosophy: it is not the world (*an sich*, in itself) that presses its categories on the human brain, which leads to immediate and correct knowledge of the world. It is us, who form the objects, through the categories of our mind. These are *a priori*; they are part of us, before we look upon the world or before we can even begin to gain knowledge about the world. *"In other words, our empirical 'synthetic' knowledge is infused by elements that do not come from the external world, and that are thus 'a priori'."* (Ruse, 1991: 194). The knowledge relation between the knowing subject and the world hence is interpreted as an indirect knowledge relation. We perceive the world with our senses, however, only when we *think* the incoming information with our mind (in a language-like fashion), can we gain knowledge. Knowledge, therefore, is based upon experience, but interpreted by the mind (Ruse, 1991:194).

2.3. Logical Empiricism

Logical empiricism (also known as Neopositivism) came along with its adherents who argued that they knew that the world out there was structured in an orderly fashion, and that we could formalize this natural order in the world within a language-like system called logic (Gibson, 1998), from wherein we could deduce eternal truths about that world. Developed out of nineteenth century positivist thinking, Neopositivists adhered to the view that only science, as the most enlightened stage in history, could develop truths. These truths would be reducible and deducible from information gathered by our sense organs and somehow we would be able to form *Protokolsatze*, *observational sentences* as they called them: sentences that describe, no, correspond to elementary facts in the world, and this in an immediate fashion. Mathematics and logic were conceived of as instruments: objective measurements used to gain knowledge from the world. Simple observations somehow would immediately transform into verbal expressions (Munz, 2001: 50).

Wittgenstein (1989), however, showed, that we cannot say that language refers to a world out there. The early Wittgenstein, as Bertrand Russell, for example, pointed out before him, adhered to the view that the structure of the world and the structure of language are the same: language and the world show a structural resemblance. More problematic, however, is the fact that, according to Wittgenstein, we cannot say (although it somehow shows) that language refers to the world out there, that for instance the word 'cat' refers to the animal we see and call a cat, so we would never be able to talk about eternal truths out there. Thinking is always thinking based upon language, and we cannot talk about this kind of thinking without using language. Hence, his famous statement that the boundaries of my language are the boundaries of my world (Wittgenstein, 1989: 5.6).

2.4. Language Games

The early Wittgenstein subscribed to the view that logic is an objective instrument, and, therefore, a universal language. The later Wittgenstein (1989) stated in his *Investigations* that words do not straightforwardly or solely refer to objects in an external world, instead words can have different functions and different meanings. Language is not solely an instrument of knowledge either, because we can use language for contact and communication between members of the same language community, as well. Hence, the introduction of the concept *language games*, in the plural: language can have many manifestations. Because of this he introduced the term 'family resemblance'.

The meaning of words does not lie in their possible referential relation to the world, but in their use. What matters is how these words are being put to *use*, by members of the same community that partake in different language games. Therefore, language has a *social* function: it enables social relations between members of the same community that make use of the same language. Meaning, therefore, also is explained as being intersubjective, excluding all possible forms of a private (inner, non- or pre-linguistic)-language (Munz, 2001): meaning and language hence are externalized and are supposed to be part of a (social or cultural) community.

The concept *meaning* is, therefore, introduced for the first time, and this notion is distinguished from truth. Meaning is a secular concept and can only be part of secular thinking, because meaning becomes relative to the community, and what is comprehended as meaningful is dependent upon and restricted to the language community in which we are born. One can only talk about truth in a religious framework or from within naïve realism, because here a correspondence between language and the world is presumed to exist.[2]

[2] As we shall discuss later on, these ideas gave way to the idea that when studying language (from an evolutionary view or otherwise), one is studying the social or the cultural (the Sapir-Worf hypothesis) and the general relativistic accounts as defended by post-modern sociology and anthropology, that conceive of subjects as determined by society, and knowledge as an idealistic non-existing phenomenon.

2.5. Strange Encounters

All of this might and should look strange to anthropologists, who conceive of language as a medium through which people partly express their feelings, and it might look strange to linguists as well, because they understand language first and foremost as a communicative system,[3] while biologists or neurologists should also be surprised, because they know that impressions or information coming from our sense organs does not get magically transformed into language. Nonetheless, Western philosophers have always regarded language as an instrument to gain knowledge about the world.

Within classical Western philosophy, beginning with the ancient Greeks, language, reason and thinking were referred to synonymously as *logos*, a principle that brought order into the world. Language, according to this view, allows us to order the world in a logical way. The idea, therefore, has always been that with language, we can develop true statements about the world, because every knowledge relation and every form of thinking is conceived of as a language relation.

With Wittgenstein, and the failures of positivism and logical-positivism, philosophy is declared bankrupt: the reference problem (how our language relates to the world) cannot be explained from within philosophy. Albeit the fact that analytical philosophy, as a discipline within the field, still goes on in a somewhat modified version, two reactions to this failure can be distinguished: *philosophy is dead* and *long live philosophy*.

Those who respond that because of the failure of logical empiricism, 'philosophy is dead', can be classified as post-modern thinkers. Those who respond, 'Long live philosophy!', can be classified as Naturalized Philosophers or Evolutionary Epistemologists.

2.6. Sociology of Knowledge

Sociology of knowledge (SoK) is part of post-modern thinking because it regards knowledge, not as a relation between a knower and the world, but as a relation between different knowers (Munz, 2001: 106). Knowledge hence, becomes a *sociological* problem, instead of a philosophical one. Beginning with Hegel, and culminating with Durkheim and Foucault, the only thing relevant and real, becomes the *social*. And the social is reified as part of a deeper lying structure or some superorganic structure. The social as an entity can do things to people; it can *work causally*, thereby rejecting the possibility

[3] These views, however, are the direct result of the secular philosophical traditions (discussed in note 2). There is a reason why we nowadays emphasize the role of the social and the cultural so strongly, when studying (the evolution of) language and culture.

of any form of creativity or emancipation of the individual. Science can and should only be explained from within society: science and scientific thinking is the expression, they say, of cultural and social tastes, and those tastes are the expressions of those groups within society who are the most powerful. Science, however, has nothing to do with gaining knowledge about the world, and, hence, we see the introduction of terms like *regimes* or *epistèmes* (Rabinow, 1997: 31–34). All one needs to do, according to this view, is deconstruct all scientific theories ever developed, see whose cultural and social ideas are being promoted and answer the questions: who has got the power and why did they want it in the first place.

> What Foucault has called the regime, or game of truth and falsity is both a component and a production of historical practices. [...] Truth is linked in a circular relation with systems of power which produce and sustain it, and to the effects of power which induce and which extend it. (Rabinow, 1997: 35–36)

Sociological systems theory was born and implemented within different disciplines such as history, science, culture and language. These should be comprehended as closed self-containing, self-explaining systems. These systems develop in and from within themselves and can only be explained from within these systems, in a *synchronic* way (Munz, 2001: 122–123). Wittgenstein's language games, Malinowski's (1949) social, functional anthropology, Talcott Parsons' functionalist sociology (1964), Foucault's regimes/epistèmes/discourses, de Saussure's linguistics and Kuhn's paradigms (1996) have the following in common: all turn away from evolution, all turn away from *diachronic* studies, all defend synchronic studies, all reject bridge laws or continuity between earlier and later or geographically distinct, sciences, cultures or languages ... Why? Evidently because they wanted to ban *historicism*, with its developmental laws. Meaning, language, science and culture are all understood as systems that need to be explained from within these systems, because there exists nothing outside the system: there is no God's eye view, nor does there exist anything besides the social and/or cultural domain. Meaning becomes *variant*, and is defined by the time and place, the community of which we are part, which eventually leads to the introduction of concepts such as *incommensurability*.

2.7. Naturalized Epistemology

When interested in language or culture, neither analytical philosophy nor SoK, taken on their own, can help us: we need to study evolution, biology, embryology, child development ... and here we need to be able to distinguish scientific ideas from misfits.

A much more optimistic view is, therefore, given by EE. EE grew out of naturalized epistemology (NE), a term first introduced by Quine (1969). Instead of trying to ground science, outside of science, in a first philosophy, we should ground science, in science itself. *"[. . .] The quest for a foundation outside of science upon which science can be grounded (i.e. justified or rationally reconstructed) is a will-o'-the wisp and, therefore, ought to be abandoned."* (Gibson, 1998: 668). In other words, the foundations of scientific thinking can and should be based upon scientific theories, and, therefore, epistemology should get naturalized. This does not mean that philosophy is dead, according to Quine's view; it still goes on, as a part of the natural sciences (and natural sciences here are conceived broadly, including physics, biology, psychology and social sciences). NE is not merely a descriptive discipline that records how we can gain knowledge using different sciences, it is also normative: it adheres to the view that it is *only* by making use of sciences, that we can gain insight into the knowledge relation and that knowledge can be founded.

> [. . .] [A]t this point it may be more useful to say that epistemology still goes on, though in a new setting and a clarified status. Epistemology, or something like it, simply falls into place as a chapter of psychology and hence of natural science. It studies a natural phenomenon, viz., a physical human subject. This human subject is accorded a certain experimentally controlled input—certain patterns of irradiation in asserted frequencies, for instance—and in fullness of time the subject delivers as output a description of the three-dimensional external world or its history. (Quine, 1969: 273–274)

Naturalizing epistemology for Quine meant that somehow psychology would show us how our language which we use to gain scientific knowledge about the world, relates to our brain which receives sensory information from that world. Psychology would show us the relation between our neural input and observational sentences, sentences that are associated in a direct way with sensory stimuli. And the reason that we humans would all have the same sensory stimuli is that we all evolved by natural selection and all human beings share the same biological constitution. *"... [T]he observation sentences are the sentences on which all members of the community will agree under uniform stimulation."* (Quine, 1969: 276).

This, however, still implies that all languages are *commensurable* with regard to observational sentences, and that somehow the relation between sensory input and language is direct.[4] Neurology today, however, has already

[4] Indeed, there is a reason why linguists search for linguistic universals and that anthropologists search for cultural universals.

shown numerous times that our brains do not carry any language-like labels (Changeaux, 1985; Edelman, 1987; Gazzaniga, 1994, 1998, 2000; Damasio, 1996, 1999; Ledoux, 1998). Regarding theoretical sentences, sentences that are more complex and that cannot be reduced to observational sentences, Quine subscribed to a *relativistic* view: these sentences are *incommensurable* and hence a SoK or social constructivist position is taken by him. Any reference to the external world, however, is underdetermined according to Quine (Levinson, 1998), for knowledge is about the relation between neural input and observational sentences and the relation between observational sentences and theoretical sentences. Therefore, all our knowledge of the world is filtered by our sense organs that are the products of evolution (Gibson, 1998: 681).

3. EVOLUTIONARY EPISTEMOLOGY

"In short, evolutionary epistemology is an epistemological system which is based upon the conjecture that cognitive activities are a product of evolution and selection and that, vice versa, evolution itself is a cognition and knowledge process." (Wuketits, 1984: 2).

EE, a term first coined by Donald T. Campbell (1974), developed out of NE, but also goes further than NE. Whereas Quine still believed that the natural sciences would somehow show the exact relation between the world, humans and the language uttered by human beings, EE gave up on this idea. The anthropocentrism of Quine cleared room for the idea that all organisms *re-present* their environment, and that all organisms engage in a knowledge relation with the environment because of the workings of natural selection. EE not only examines the relation between human, language-like knowledge and the world: it regards every relation between an organism and an environment as a knowledge relation, irrespective of whether or not these organisms have language. EE understands the knowledge relation not as a relation between a knower and a knowable world, nor as a relation between different knowers, but rather as a relation between an organism and its environment (Munz, 2001: 9).

3.1. Traditional EE

EE is a branch within NE that examines evolutionary processes that form the basis of our knowledge-gaining-process. It searches for analogies between biological evolutionary processes and the evolutionary processes of science, culture and language. These evolutionary processes, however, are reduced to the mechanisms of natural selection, as the standard definition given by

Michael Bradie and William Harms in the *Stanford Encyclopaedia of Philosophy* shows:

> Evolutionary Epistemology is a naturalistic approach to epistemology, which emphasizes the importance of natural selection in two important roles. In the first role, selection is the generator and the maintainer of the reliability of our senses and cognitive mechanisms, as well as the 'fit' between those mechanisms and the world. In the second role, trial and error learning and the evolution of scientific theories are construed as selection processes. (Bradie and Harms, 2001:1)

This means, first of all, that because of the mechanisms of natural selection we can gain knowledge of the environment by studying the organisms that live in it, and secondly, that all organisms are instruments, systems of knowledge. Whether these organisms develop language or not, have a brain or not, have sense organs or not is not relevant: all organisms represent and contain knowledge about the world out there.

Since organisms evolved by natural selection and only those organisms that are adaptive to the environment live long enough to reproduce, organisms become representations of their environment. Organisms that fail to survive long enough to reproduce, and, hence, are maladaptive to the environment, are conceived of as hypotheses which got falsified in the Popperian sense of the word (Popper, 1974).

Every relation that an organism engages in with its environment is regarded as a cognitive relation, a knowledge relation, this knowledge itself being the result of the workings of natural selection.

So knowledge-gaining-processes are not only understood as the products of biological evolution or as a biological phenomenon, the knowledge-gaining-mechanisms themselves are regarded as knowledge.

And the theoretical models from evolutionary biology are also implemented to study the products of these knowledge-gaining-mechanisms.

3.1.1. The EEM- and EET-programme

EE is about developing a normative framework based upon evolutionary thinking. Natural selection *strictu sensu*, only focuses on the *external* relation between the phenotype and the environment: the *level* where natural selection selects the adaptive ones, in an indirect way, by weeding out maladaptive organisms.

However, because organisms, as a whole, are the product of evolution and some organisms develop language and culture or science, the *products* of these biological organisms are also proposed to be comprehensible and explainable from within evolutionary theory.

EE, therefore, no longer distinguishes between ontogeny and phylogeny, but tries to explain organisms and also the cognitive products of these organisms, from within evolutionary theory.

Michael Bradie and William Harms (2001), therefore, distinguish between the evolution of epistemological mechanisms (EEM) and the evolutionary epistemology of theories (EET) programme. The EEM programme on the one hand studies the development and evolution of knowledge-gaining-mechanisms (broadly conceived as including the central nervous system, the brain, the sensory-motor system . . .) of all living organisms. The EET programme studies the evolution of ideas, theories, cultures . . . the products of these knowledge-gaining-mechanisms, from within evolutionary models, by analogy.

Especially within the EEM-programme, there is a general consensus that the Modern Synthesis—Darwin's theory of natural selection combined with population genetics based on Mendel and mathematizised by Fischer, Wright and Haldane (Schwartz, 1999)—is sufficient to explain the evolution of knowledge-gaining-mechanisms. Within the EET-programme, there is more discussion going on about whether selectionist models alone can suffice in explaining the evolution of culture, language or science.

The Modern Synthesis (Ayala, 1978; Mayr, 1978, 1983; Maynard Smith, 1993) adheres to a strict distinction between ontogenesis (the development of an individual from conception until death) and phylogenesis (the origin and evolution of species). If this distinction is not made properly, one repeats Haeckel's biogenetic law which states that *ontogeny recapitulates phylogeny*: during development, an individual passes through the evolution of the species. Phylogeny is explained using natural selection, at the *micro-level* (the variation and evolution within species) and the *macro-level* (the evolution of new species by speciation). Ontogenesis is not explained by the Modern Synthesis: it only subscribes to the view that a genotype lies at the basis of a phenotype (Gontier, 2004).

Natural selection, according to this view, works at the level of the interaction between the phenotype and its environment, and here the environment selects the organism, while the organism is comprehended as a passive element of that evolution: either the organism is adapted to its environment, which means that given its phenotype, the organism can survive long enough to reproduce; or else it dies and does not get selected, because the genes of this organism are not passed on to the next generation (Gontier, 2004).

3.1.2. Internalizing evolutionary theory and the units and levels of selection debate

Deviations from this paradigm lead to a position in which the strict distinction between ontogenesis and phylogenesis is no longer made. A new trend in biology states that selection does not only work at the *level* of interaction between the organism and the environment, but that it can also work at other levels, selecting *units* other than the phenotype as well.

Hence, with EE natural selection got *internalized*, thereby raising questions about the *units* and *levels* of selection (Brandon, 1982; Brandon and Burian, 1984).

Richard Dawkins (1983, 1984, 2000) for instance, was one of the first, together with George Williams (Schwartz, 1999), to state that the *unit* of selection is not the phenotype, but the individual gene, and that the level of selection can be the environment, but it can also be other genes within the genome.

The ideas of neural Darwinism, as defended by Changeaux (1985), Edelman (1987), Gazzaniga (1994; 1998; 2000) or Sperber (2001), are indeed the products of this kind of thinking: natural selection is internalized and is proposed to work at the level of brain development, the unit of selection being individual neurons or perhaps even modules.

This debate over the units and levels of selection, which more appropriately should be called the discussion over the units and levels of evolution, results in the search for a universal (selection) evolution mechanism, that can be understood as a theoretical framework from wherein we can explain all of evolution.

There are, however, numerous accounts already of what exactly this universal mechanism consists of. There is the *blind variation and selective retention-scheme* of Donald Campbell (1959, 1960, 1974, 1977, 1987, 1996; Heyes and Hull, 2001), *Universal Darwinism* put forward by Richard Dawkins (1983), *Universal Selectionism* introduced by Gary Cziko (1995), the *generate–test–regenerate-scheme* of Henry Plotkin (1995, 1996) and the *replication–variation–environmental interaction-scheme*, first introduced by David Hull (2001). All these theories focus on the theory of natural selection as it is applicable to genes. The evolution of genes by natural selection is of course the best reported kind of evolution and, therefore, extrapolations start from here, thereby reducing this theory further to adaptationist accounts.

3.1.3. Problems with universal selectionist accounts

"*In all versions of EE, Panglossian adaptationism must be avoided. [...] Selection Theory emphasizes the role of 'retention' (and hence tradition) fully as much as variation and selection.*" (Campbell, 1987: 140).

Evolution is the phenomenon we want to explain, natural selection is only a theory that tries to explain the phenomenon of evolution.

The late Stephen J. Gould (1980, 1982, 1984, 1991) and Richard Lewontin are amongst the most well known biologists who criticize these ideas: the former, together with Niles Eldredge, developed the theory of *punctuated* *equilibrium* which states that natural selection does not work gradually, that small random mutations do not slowly result in the evolution of new species, but that we encounter long periods of stasis within evolution, and that these periods get punctuated by short periods of rapid changes.

Lewontin (1978, 2000) is known for his ideas about *niche construction*: organisms are not passive objects who are selected or do not get selected by the environment. Organisms are actively engaged in their own development and perhaps even their evolution, because they systematically form and reform their environments in an active way.

The problem with universal Darwinism and universal selection accounts is that it reduces evolutionary thinking to Neo-Darwinian thinking. For it states that theories which mainly got developed by zoologists—people who study animals, not bacteria, nor plants, fungi or protists—can get universalized to explain all of evolution (Margulis and Sagan, 2002). The blind variation and selective retention scheme, the generate–test–regenerate-scheme, all the proposed schemes, try to develop a normative scheme of evolution which, in turn, is analogical to the evolution of genes by means of natural selection.

And they want this scheme to work, not only in this world at all levels of life ranging from unicellular organisms to the evolution of humans, but in all possible worlds as well. They also want to explain the evolution of language and culture using these schemes. They attempt to do this by implying that there are elements such as genes which vary and mutate, are selected and evolve within the evolution of language and culture. Hence, the success of *modularity theory* (Sperber, 1996; Whitehouse, 2001) and *memetics* (Blackmore, 1999).

These theorists oversimplify. They forget that there are two kinds of genes, structural and regulatory (Gehring, 1998; Davidson, 2001), and that only structural genes behave in a Mendelian fashion, while *regulatory genes* can influence ontogeny and phylogeny, by switching structural genes on or off, through the proteins they encode for, in a non-Mendelian fashion (Gontier, this volume).

These zoologists forget that two-thirds of the evolution of life took place within unicellular organisms, organisms that do not behave in manners explicable by natural selection alone. The development of multicellular organisms was the result of symbiotic mergers, as Lynn Margulis's theory (Margulis, 1999; Margulis and Sagan, 2000, 2002) shows: bacteria merged, whole bodies fused together and then developed into eukaryotic, multicellular organisms. Species do not only develop as a result of speciation, they also can develop as a result of horizontal mergers (Gontier, this volume).

And zoologists forget how physics can help the study of evolutionary processes. As the mathematician Ian Stewart (1999: 88) has said: *"Nobody is silly enough to think that an elephant will only fall under gravity if its genes tell* *it to do so, but the same underlying error can easily be made in less obvious circumstances."*

The time that physics was about studying timeless universes, where unchangeable laws determine everything that has happened, is, and ever shall happen, is long gone. New physics, systems theory, chaos theory, complexity theory, as developed by the late Ilya Prigogine (1995, 1996), René Thom, Stuart Kauffman (1996) and Freeman Dyson (1990), are about trying to develop a framework that can be put to use to study evolution, by the introduction of terms like self-organization, bifurcations, phase transitions, irreversible processes and so on. Olaf Diettrich (this volume) and Diederik Aerts, Marek Czachor and Bart D'Hooghe (this volume) will explain how physics and quantum theory can help the study of cognition and language, while Bart de Boer (this volume) will explain how we can also formalize these theories using artificial intelligence in order to study language.

3.2. New EE

All ideas defended by what I call traditional EE's still adhere to the view that we can develop a correspondence theory: that there is a one-to-one correspondence between the environment and the organisms who live in it. As Konrad Lorenz pointed out (Riegler, this volume; Wuketits, this volume), this does not mean that the hooves of a horse have to be like the steppe land on which they walk, but that the way the hoof of a horse is shaped gives us a correct and true theory about how the steppe land is. This idea, however, implies that natural selection is reduced to the mechanisms of adaptation, for it is only the idea of adaptation that can lie at the basis of such a correspondence theory.

A whole different story develops when we look at *developmental systems theory (DST)* (Maturana and Varela, 1980; Oyama 2000a, 2000b; Dupré, 2001), which perceives organisms as autocatalytic systems: systems which are able to self-organize and self-maintain, not so much because they are adapted to the environment they live in, but because they are able to self-maintain due to the inner mechanisms they develop in order to survive (Gontier, 2004). These inner mechanisms of self-organization and self-regulation can contradict the world out there: instead of being adapted to the environment, organisms maintain themselves, sometimes even despite the environment they live in (Gontier, 2004). Because of the rise of biological systems theory, the idea that organisms are passively selected by an active environment is put to rest. Organisms are understood as beings that largely construct their own environment in an active way, for example, by habitat or niche construction (Lewontin, 2000). Therefore, these inner mechanisms of self-organization and self-regulation are comprehended as *causal* factors that need to be part of the *explanation* of *why* organisms behave in a certain manner, rather than focussing exclusively on the external relation between an organism and its environment. In contrast to the perspective of sociological systems theory, organisms are comprehended as partly open, partly closed systems (Kauffman, 1996; Prigogine, 1996). They are *closed* because they distinguish themselves from the environment through the formation of a membrane, or skin, whereas they are *open* because they constantly interact with the environment they live in, thereby influencing and (re)constructing that environment as well. Therefore, the relation between an organism and its environment is comprehended as being *dialectical*, instead of *dualistic*. As Richard Levins puts it:

> Organisms (a) select their environment, (b) actively modify their environment by their own activity, (c) define their environment in terms of relevant variables, (d) create new environments for other organisms, (e) transform the physical nature of an environment input as their effects percolate through the developmental network, (f) determine by their movements and physiological activity the effective statistical pattern of environment, and (g) adapt to the environmental pattern that is partly of their own creation. Further, each part of the organism is 'environment' to the other parts. The conclusion of (d), (f) and (g) that organisms adapt to and create statistical patterns of environment finally suggests that the utilization of resources by populations not only uses up ecological opportunities but also create new ones: The variability in resource level may itself behave as a resource. . . . The traditional separation of the world into organisms and environment as mutually exclusive classes . . . leaves us with the task of then connecting them. A more dialectical approach emphasizes the mutual interpenetration of organism and environment. (In Hahlweg, 1989: 61)

In this case, adaptation does not mean that an organism is adapted to an external world, but that an organism is able to change its environment to enhance its *survival*. And adaptation does not mean that an organism is able to reproduce at maximal rate (as implied by the term fitness), but it means that an organism can *survive* and *self-maintain*. *"Organisms do not simply correspond to their surroundings and do not get everything that is 'out there' but rather form their own 'picture' of what is around and react adequately, according to the specific requirement of their lives, i.e. for the sake of survival."* (Wuketits, 2001: 178). Non-adaptationist views, therefore, cannot adhere to a correspondence theory; instead they make use of a *coherence theory* (Wuketits, this volume).

Those theories that I characterize as new EE are especially part of a German tradition: Wuketits (1984, 1990, 1992, 1995, 2001, this volume), Riedl (1984), Kasper (1984) do not adhere to a universal selectionist account but state that EE has to be based upon biological systems theory, where the notion of adaptation, with its connotations of progress or increase in correspondence needs to be replaced by the concept of self-regulation, which implies a coherence theory (Diettrich, this volume; Riegler, this volume; Wuketits, this volume).

Cybernetics models do not fit into to the EEM (form)—EET (function) dichotomy either. This is because there is a strong analogy between the products of the knowledge-mechanisms and the knowledge-mechanisms themselves (Hahlweg and Hooker, 1989a, 1989b; Hooker, 1989).

Cognition and the cognitive capacities themselves (the form and the function) are comprehended as a function of active systems which actively interact with their environment. *"Hence, the crucial question is not how animals and humans have evolved through adaptation to a given environment, but rather the interactions between organisms and their environment(s)."* (Wuketits, 1995: 359).

An EE based upon systems theoretical evolutionary theory, therefore, is not *anti*-adaptationist; it is *non*-adaptationist (Wuketitis 1995: 359–360), because there is no constant unchanging world out there that an organism is passively adapted to. The world out there changes constantly by actively engaged organisms that are busy enhancing their survival.

4. EE AND CULTURE

4.1. Mathematizing Culture?

EE first started the study of culture almost 25 years ago, beginning with the work of Luca Cavalli-Sforza and Marcus Feldman (1981). Based on mathematical population genetics, they developed a *theory of cultural transmission*, the unit of evolution being cultural traits. These cultural traits, they said, could evolve and often did evolve more in accordance with neutral evolutionary theory (Kimura, 1976). As a result, these investigators used concepts such as genetic drift, because most cultural traits neither harm nor enhance the reproductive success of its carriers, rather, they are neutral.

At the same time Charles Lumsden and Edward Wilson (1981) were developing their theory of *gene–culture co-evolution*. Again using mathematics to formalize culture, they stated that human cultural transmission is ultimately gene–culture transmission (Allot, 1999: 68). They developed the ambitious idea of tracing development all the way from genes through the mind to culture, thereby paving the way for epigenetics, sociobiology (Laland et al., 1995; Day et al., 2003; Ehrlich and Feldman, 2003), and evolutionary psychology (Cosmides and Tooby, 1994; Barrett et al., 2002). They stated that the unit of selection and hence the unit of inheritance, was the '*culturgen*', which included artefacts (material remnants, the topic of research of archaeology) and *mentifacts* as they called them, that is, mental ideas or behaviours.

Robert Boyd and Peter Richerson (1985) soon followed their lead, presenting a *Darwinian theory of the evolution of cultural organisms*. Culture, in their view is described as the transmission from one generation to the next—through teaching and imitation—of knowledge, values and other factors that influence behaviour (Allot, 1999: 68). Their dual inheritance theory was based on the idea that genes and cultures are analogous: both genes and culture are the sole determinants of behaviour.

Later on *memetics* was born (Blackmore, 1999), that is, after Richard Dawkins proposed that as genes are the sole determinants of biological behaviour, so *memes* act as infectious ideas. Ideas, that just like viruses, work in an epidemiological fashion.

Tim Ingold's reaction to these theories does not leave much to the imagination:

> Not so much can be said for these models in their present state of development, the assumptions on which they rest are either so remote from reality or so ultimately trivial that they do not so much advance our understanding of evolutionary processes as provide an excuse for the exercise of mathematical ingenuity. (Ingold, 1986: 364)

In other words, these theories mainly got developed by biologists and mathematicians who were not schooled in culture, and hence were not sufficiently acquainted with this subject matter in order to develop adequate models, although their intentions were of course good.

4.2. Post-Modernism?

Anthropology is the discipline that suffers most from post-modern thinking, and which finds itself most in crisis (Harris, 1995). There is a reason for this: the subject matter that anthropologists set forth for itself represents the most complex phenomenon ever encountered throughout history, that is, human cultures.

The empiricist tradition, described above (2.1.), has its anthropological counterpart within *cultural anthropology*, especially within the Boasian school (Pinxten, 1999: 5). These anthropologists defended the following position: given enough observation, a detailed description of the *other* could be given, from wherein we could deduce recurrent patterns that, in turn, would lead to objective knowledge.

The rationalistic tradition has its counterpart in *social anthropology*, with the structuralists, the most well-known being Claude-Lévi Strauss, who wanted to overcome mere observations in order to develop adequate theories (Pinxten, 1999: 50–53). These scholars ended up explaining culture as part of a superorganic structure, again denying the autonomy and, therefore, agency of the individual and the group.

Both schools regard the researchers as *interchangeable*. Empiricists regard researchers as neutral *recording devices* (Pinxten, 1997: 35), while structuralists are privileged because they have a priori knowledge about the world: they know that it is structured and layered into superorganic, organic and anorganic structural levels. The *other* is regarded as an object that needs to be examined.

This *objectivistic*, *naturalistic* tendency is rejected by members of the *phenomenological*, *subjectivist* school (Pinxten, 1997: 5) who regard their research themes as subjects. These subjects cannot be explained from outside the cultural system. Rather they need to be explained from within this closed, self-encapsulating system, using the folk categories of these subjects to explain how these people *intuitively feel* their culture (in a hermeneutic *einfühlende* tradition). Hence, the success of *participant observation* (we learn from them by becoming one of them), a fieldwork approach first introduced by Malinowski. Hermeneutics also defend the post-modern idea that cultures are incommensurable, a position that thereby rejects any scientific theory that is able to compare different cultures, in order to develop a generalized model of culture (evolutionary or otherwise).

So, basically, until recently only two positions could be taken up by an anthropologist, interested in culture: an *emic* position or an *etic* position (Lett, 1990: 130–131) which correlate, respectively, with an insider and outsider position (a conceptual opposition borrowed from the contrast between *phomemics* and *phonetics* in linguistics). *Emic* constructs make use of the terminology and perspective of the (native) informants to explain their culture while *etic* constructs use the (universalist) terminology and perspective of the scientific community.

The whole point, however, is that, within both positions only the scientist decides what (s)he encompasses in his/her theory because only (s)he can obtain *objective* knowledge of the other (Pinxten, 1997: 36).

Hermeneutic traditions differ from naturalistic traditions within anthropology (Bloch, 1998a: 40–41) because they call into question the possibility of an anthropology as science altogether. In contrast, *naturalists* emphasize that anthropology needs to be reconciled with other scientific endeavours, by the use of objective, measurable and quantitative fields. In this latter tradition, Sperber (1998: 16) goes so far as to state that anthropology is not a science: it does not study something material, it studies meanings and interpretations of different groups. Rather he views anthropology as an objective, scientific tool that gives objective concepts from wherein we can explain all of culture while these concepts themselves share a form of family resemblance. An example that he gives is the concept *marriage*: thereby implying that some relations between individuals, within all cultures, can be explained as marriage (Sperber, 1998: 21).

Hermeneutics even goes so far as to regard anthropology as a form of literature: according to Clifford Geertz (1973), for instance, each description is an interpretation and cultures are just texts that need to be read, thereby doing what this discipline never intended to do: materializing their subject matters.

> Anthropology has always posed this problem for science: by showing us that everyone is embedded in a cultural matrix of meanings, it makes clear that all truth, reality, and certainty are local orthodoxies [. . .]. This postmodernist movement has embraced this finding and forged it into a devastating weapon against all efforts to ground theory in empirical data. (Johnson, 1995: 13)

A third position to take has been developed recently, by Bourdieu (1979) and Pinxten (1997), called the *praxiological* position.

> It aims at combining the objectivist and the subjectivist approach: the external knowledge of 'the other' is internalized by the researcher and the introspective knowledge of the researcher is externalized into the subject of research at the same time. The dialectic between both movements allows for a full understanding of cultural phenomena. (Pinxten, 1997: 68)

Now here is where EE fits in. This is because of the fact that we need to look at biological, neurological and cognitive learning theories in order to understand how external knowledge is internalized and how introspective knowledge is externalized. Moreover, we need to know how we obtain this introspective knowledge in the first place, how we are able to explain this in a meaningful way to others, and how others can understand this knowledge, ending with general agreed upon knowledge shared by different members of the same or diverse communities. And here is where embodied, ethnographical and cognitive sciences fit in (see for instance Ingold, 1986; 2000; 2001; Strauss and Quinn, 1993; Shore, 1996; Dupré, 2001; Whitehouse, 2001).

4.3. What is Culture About?

Most people not schooled in anthropology still define culture as the higher arts, or as literature or going to the theatre. Some think of those exotic Pygmies in Africa or the Maori from New Zealand. But almost nobody thinks of culture as going out and having a drink with his/her friends, or nipping from a glass in a certain way, or looking somebody straight in the eyes or avoiding eye contact at all times.

Some logicians still find it amazing to hear that people think in contradictory ways, that, for instance, a child knows that people die, but believes that Santa Claus lives forever. Yet that is what culture is about. Anthropology is not about distinguishing true from untrue; it is not about finding contradictions or paradoxes that need to be solved. Rather it is about coming to understand *how* and *why* these people have contradictory ideas. And indeed, these contradictory ideas are starting to get formalized as well: the development of default logics within artificial intelligence and paraconsistent, inconsistent and adaptive logics within philosophy, are disciplines that look very promising.

Biologists interested in formalizing culture, analogous to the evolution of genes, search for the unit(s) of cultural evolution that is (are) passed on from one generation to the next, and this in a most faithful way. Hence, we encounter concepts like culturgenes that include artefacts and mentifacts.

Anthropologists have been studying these phenomena for a long time. *Cultural materialism* (Harris, 1995), a subdiscipline within anthropology, years ago tried to study culture through the examination of artefacts, and artefacts here included ideas, that, in good sociological tradition, were 'materialized' as part of the superorganic. They developed diffusionistic models in order to determine how ideas or artefacts came into existence and hence spread throughout the world. All they discovered was that their models did not work, because when studying complex phenomena like, for example, *cargo cults* (Englund and Leach, 2000; Douglas, 2001), they saw that the Christianity preached by the missionaries was not learned nor transmitted without being changed. All they heard was that Jesus was a black man and church rituals got mixed with voodoo or other local customs. It is difficult to find units of culture that are transmitted faithfully as genes are passed on faithfully from one generation to the next.

The same idea, adhered to by a different individual, living in a different context, a different culture, can get interpreted in a wholly different way (see, for instance, Dupré, 2001). And again, it is not about right or wrong; it is about formalizing these kinds of evolution because this is what culture is about.

Anthropology is about the 'Benz mammas' in Africa (Fox and Sannwald, 2003), women referred to in that way because they all drive a Mercedes-Benz, because they got rich working the land, during and especially after colonization. In some African cultures, men did not work the land and hence stayed poor. The implementation of one element, Western capitalism, thereby changed the social structure from a patriarchy to a matriarchy.

These are the processes that need to be formalized and beg for a normative framework, for it is only when we gain more insight into present conditions that we can know what to look for in the past.

5. EE AND LANGUAGE

It is only recently that EE also began to express an interest in language. In 1866, the *Société de linguistique de Paris* banned all studies concerning the origin of language and/or the development of universal languages[5] (Lock and Peters, 1999: vii).

Afterwards, Chomsky (1967) came along, saying that language was innate and uniquely human. Chomsky never denied that language needs to be studied from within biology, but because of the uniquely human part, it was not useful, according to him, to study language from within evolutionary biology. As most philosophers, he defends the idea that humans are qualitatively different from all other animals, because they have language. Within Western philosophy, as said, there has always been a group that defended the idea that with language, humans can come to everlasting truths; it is just a matter of finding the right structure.

Steven Pinker and Paul Bloom (1990), in their by now famous article in *Behavioural and Brain Sciences*, written almost 15 years ago, have as their main aim synthesizing Chomsky's ideas with Neo-Darwinian thinking and modularity theory: natural selection should have evolved a grammar module or different modules that resulted in language. Natural selection, they say, designed a human language faculty, a language acquisition device (LAD) that takes on the form of a grammar module, the latter being the unit of selection. To be more precise, according to this view, the language module is the result of different modules and pre-adaptations that did not evolve to form language, but somehow they did, as the spandrels of San Marco are the most beautiful attractions, while they were made to support the cathedral's walls. But *how* can language be coded for in our genes? Pinker and Bloom (1990) are not quite clear on this matter. All they say is that language shows design, and, therefore, it *should* have and *must* have evolved by natural selection.

[5] The fact that the society also banned any investigations concerning universal languages is often ignored in the literature, although it is a rather important piece of information. EE after all, is the endeavour to extract a formal scientific framework from evolutionary thinking that can function as a universal (evolutionary) language to explain all phenomena that show signs of evolution.

Two years ago, Hauser et al. (2002) distinguished between the faculty of language in the broad sense (FLB), and the faculty of language in the narrow sense (FLN). They stated that only the FLN is uniquely human, whereas the mechanisms that underlie the FLB are probably shared with most higher animals. In their article, they also adhere to a modular view of cognitive evolution, stating that most aspects of the FLB probably developed in a modular and highly domain specific fashion, and that humans have the unique capacity to transcend these modules, because they developed a domain-general system.

And of course there are the works of James Hurford, Michael Studdert-Kennedy and Chris Knight (Hurford et al., 1998; Knight et al., 2000). The merit of these people is that they bring together different authors from within different disciplines that study language, thereby showing how interdisciplinary the field of language research is.

The field of language research can, however, still grow bigger, and must be conceived of not only as an interdisciplinary endeavour but also as a transdisciplinary one, an endeavour that includes physics, for example, and acknowledges the important role philosophy of science in general and specifically EE can play. For what is the *unit* and the *level* of language or cultural (or social) evolution? Answering this question means bringing EE to bear on these fields.

William Croft (2000) is the first one to actually use one of the proposed universal schemes put forward by evolutionary epistemologists: he tries to develop a theory of language evolution and variation, using Hull's *replication–variation–environmental interaction-scheme*. However, he immediately states that because languages, just as cultures, mingle all the time, e.g., because of warfare, trade, or culture contact, a *plantish* approach might better suite the purpose. Here he is referring to the fact that the evolution of language takes on a form that is more analogous to plant hybridization, rather than the mere vertical evolution that is more characteristic of animal (Neo-Darwinian) evolution.

And, indeed, that is what studying language is all about: it is not about finding an entity that is passed on faithfully from one generation to the next. Languages are not static entities but change constantly, by the introduction of new words, through the blending of grammatical structures as a result of culture and language contact, aspects of language change that have been described already by sociolinguists. These are the mechanisms that beg for a normative framework so we can go beyond mere descriptions to find scientific explanations (Gontier, this volume). Again, if only to know what to look for in the past.

6. CONCLUSION

By now, it should be obvious that EE is very important for the study of language and culture and I would like to end this introduction with a more personal note, on how I perceive EE. I regard EE as a positivistic discipline and as the only possible response to post-modern thinking, for it still adheres to the idea that science, broadly conceived, ranging from physics, through biology to the life sciences, can explain, in the long run, complex phenomena such as life, language and culture. Of course, this endeavour cannot be a one-man job, inter- and transdisciplinary scholarship has become an absolute necessity.

Up until today, the only theories that are not rejected by the scientific community are evolutionary theories (which does not mean that they cannot be subject to revision). That is because evolution is a phenomenon. This is a fact that shows itself and that allows itself to be proven in so many different ways.

Adherents of EE are, therefore, so bold as to make the ambitious claim that there is only one phenomenon of which we are certain, evolution, and that it is only through the study of this phenomenon that we can gain knowledge of the products of evolution.

This, also, and most importantly, means that it is simply *not* enough to study language, culture, the social, knowledge . . . by using or implementing evolutionary thinking. It, first and foremost, means that the study in itself, of language and culture, and the methods used for this study, should also be *evolutionized*. And, therefore, we need EE desperately: a general framework based upon evolutionary thinking that is applicable to all domains and products of this evolution, for this and *only* this will mark the *beginning* of a *scientific* study of language and culture.

Although the criticisms given here with respect to the fields of philosophy, physics, biology, anthropology and linguistics might sound harsh, they are not intended to be fundamentally or merely negative. On the contrary, these criticisms should be interpreted in the most positive light, because we know what needs our attention and we know what is going wrong, and, therefore, we also know how to improve upon the current theories. And, of course, it will not be easy; we will not be able to formalize complex phenomena such as culture or language overnight, but let us keep Otto Neurath's words clearly in mind, a quote that I would like to introduce as the motto of this book: *"[. . .] to he who has arrived, no satisfaction can be given, whereas he who is 'in progress' will always be grateful."* (Neurath, 1936: 6).

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Evolutionary epistemology: The non-adaptationist approach

Franz M. Wuketits

University of Vienna, Institute for Philosophy of Science, Vienna, Austria
franz.wuketits@univie.ac.at

Abstract

Earlier versions of evolutionary epistemology were based on—or at least strongly informed by—the adaptationist paradigm. It is for this reason that advocates of evolutionary epistemology have been frequently criticized by those who have adopted an *organismic* perspective in evolutionary thinking. Evolutionists defending the view that any living system—including all its characters at the anatomical as well as the behavioral level—can be sufficiently explained in terms of adaptation, have neglected the (somehow trivial) fact that organisms are active systems that do not entirely depend on their respective environment(s). Meanwhile, however, a systems-theoretical approach to understanding living beings and their evolution has made clear that (1) organisms and their environment(s) have a common history and have not evolved independent of each other, (2) any living system and its environment(s) are linked together by a feedback principle, and (3) adaptability is not defined by the environment but the organism itself. This has serious consequences for evolutionary epistemology. In this paper, I outline a non-adaptationist version of this epistemology. I also briefly discuss its philosophical implications. The main focus is the problem of realism.

1. INTRODUCTION: EVOLUTIONARY EPISTEMOLOGY

In his seminal paper published in the first volume of *The Philosophy of Karl Popper*—a highlight in the remarkable Schilpp series—Campbell (1974a: 413) states that "*an evolutionary epistemology would be at minimum an epistemology taking cognizance of and compatible with man's status as a product of biological and social evolution.*" This way he very well characterized the starting point of this type of epistemology which is firmly based on the idea of evolution, especially the theory of evolution by natural selection, and which is part and parcel of the naturalistic turn in philosophy (Callebaut, 1993; Ruse, 1986). Darwin is to be regarded as a forerunner of evolutionary epistemology, since he made clear that all psychic and mental capacities (including knowledge, thinking, reasoning, language, etc.) in humans are results of evolution by

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natural selection and thus gradually developed from particular cognitive abilities in other animals (for details see Richards, 1987). He paved the way to the basic assumption of evolutionary epistemology, namely "*that knowledge is a problem in evolutionary biology*" (Plotkin, 1987: 297). As Campbell (1974a) shows, evolutionary epistemology has a long tradition among naturalists and philosophers—Herbert Spencer, Thomas H. Huxley, Ernst Haeckel, Ernst Mach and Ludwig Boltzmann are the most prominent examples—(see also Wuketits, 1990), but has been considered a heresy by advocates of traditional (*idealistic*) philosophies. In the meantime, not much has changed in this respect, and there are still philosophers who disregard or oppose to evolutionary epistemology or even feel taken aback by the mere idea that (human) *mental life* could be described and explained in terms of evolution. (The position of evolutionary epistemology in philosophy is outlined by Gontier, this volume.)

The purpose of the present paper is not to defend evolutionary epistemology against old-fashioned philosophers who notoriously dislike evolution and do not feel comfortable with the compelling conclusion that "*if you take Darwin seriously [...] the special status of Homo sapiens is gone forever*" (Ruse, 1986: 104). I rather want to point out that there are different versions of evolutionary epistemology and to present some arguments for a non-adaptationist approach.

However, we can formulate some basic tenets that generally underlie the evolutionary conception of cognition and knowledge:

- Living systems are *information processing systems*. Information processing increases an organism's fitness and can be explained in Darwinian terms (= evolution by natural selection).
- Animals are equipped with *sense organs* and a *nervous system* (or similar structures) that produce particular *world pictures*.
- The sum-total of information-gaining and information-processing organs, the *ratiomorphic apparatus,* functions in a way similar to a calculation machine; it is analogous to, but not identical with (human) rational knowledge processing.
- Cognitive evolution may be understood as a cycle of *experience* and *expectation*. An individual organism's (ratiomorphic, preconscious) expectation (*belief*) is based on mechanisms that have been stabilized in the course of evolution by experiences made by many individuals of the respective species over many generations.
- The evolutionary description and explanation of cognition in general can also be applied to specific human cognitive capacities including scientific knowledge.

Regarding this last tenet a distinction has been made between two programs of evolutionary epistemology (see Bradie, 1986; Oeser, 1987, 1997): The evolutionary epistemology of mechanism (EEM, which deals with the biological mechanisms of cognitive systems in humans and non-human animals [natural history of cognition]) and the evolutionary epistemology of theories (EET, which means the attempt to describe and to explain ideas and scientific theories in terms of evolution). I am not going to pursue this distinction further here, however, I think that the non-adaptationist view to be presented can be applied to both programs of evolutionary epistemology.

2. THE ADAPTATIONIST APPROACH IN EVOLUTIONARY EPISTEMOLOGY

In his *Behind the Mirror,* Konrad Lorenz said that "*what we experience is [. . .] a real image of reality—albeit an extremely simple one, only just sufficing for our own practical purposes*" (Lorenz, 1977: 7). More then three decades earlier, in his classical paper on evolutionary epistemology, he had written that "*just as the hoof of the horse is adapted to the ground of the steppe which it copes with, so our central nervous apparatus for organizing the image of the world is adapted to the real world with which man has to cope*" (Lorenz, 1941 [1982: 124]). This statement clearly reflects an adaptationist explanation of cognition and knowledge which dominated evolutionary epistemology for some time. Thus, for instance, Vollmer (1975, 1984) stated that our sense organs *fit* their environment, and, as I have to admit, initially I also believed that our cognitive apparatus *represents* reality (Wuketits, 1984). Like other advocates of evolutionary epistemology in the German speaking countries, I was very much attracted by Goethe's words: "*Were the eye not attuned to the Sun, / the Sun could never be seen by it.*" In the meantime, however—Goethe's genius notwithstanding— I have adopted a more sophisticated view of cognition and knowledge; at least, I hope so.

In fact, one is easily tempted by adaptationism and its application to the (evolutionary) study of cognition and knowledge. One of the standard arguments of evolutionary biologists in the tradition of synthetic theory is that natural selection favors those organisms that are comparatively well adapted to their environment. Huxley (1958: 2) wrote: "*All evolution takes place in relation to the environment, including the biological environment, and its changes. There is a universal process of adaptation.*" According to such arguments, epistemologically relevant statements have been developed. Thus, Simpson (1963: 98) bluntly stated: "*Our perceptions do give true, even though not complete, representations of the outer world because that was and is a biological necessity, built into us by natural selection. If it were not so, we would not be here.*" Hence, the adaptationist version of evolutionary epistemology includes at least two basic assumptions:

- The perceiving apparatus of any organism is adapted to the outer world with which the organism has to cope.
- What an organism perceives is a true, but simplified picture or representation of (parts of) the outer world.

Sure, advocates of the adaptationist version of evolutionary epistemology have never thought that we humans—or other kinds of living beings—get a complete image of their respective outer world and have not been naïve realists. However, what they have maintained is that any organism's perception obeys, so to speak, to what really exists in the surroundings to which the perceiving apparatus is after all adapted. So, Simpson (1963: 98) could explicitly state: "*The monkey who did not have a realistic perception of the tree branch it jumped for was soon a dead monkey—and, therefore, did not become one of our ancestors.*"

This seems plausible. What could be wrong about it?

3. THE NON-ADAPTATIONIST APPROACH IN EVOLUTIONARY EPISTEMOLOGY

With respect to the adaptationist version of evolutionary epistemology, Lewontin (1982: 169) critically remarked that their advocates have failed "*to understand how much of what is 'out there' is the product of what is 'in here'.*" (*Out there*—in an animal's surroundings, *in here*—in an animal's perceiving apparatus.) Likewise, other authors (Gutmann and Weingarten, 1990) argued that a new organismic view is needed in (evolutionary) epistemology for the theorem of adaptation is unacceptable and invalid. These two examples stand here for a bundle of arguments that can be found in literature against the adaptationist approach in evolutionary epistemology.

Let us consider, for a moment, the following problem: How does a rabbit perceive a dog? From a naïve point of view we might think that the rabbit sees the dog the same way we humans do or that it has a *true picture* of dogs. We of course do not know how a rabbit actually perceives a dog—for, after all, we do not know how it is to be a rabbit,[1]—but even if the rabbit recognizes just a moving black spot of any significant size it seems to know what to do. Rabbits and canids (also including foxes, wolves and jackals) are connected by a long common evolutionary history, and many millions of rabbits have made the experience that what looks like a canid is something dangerous so that only running fast helps survival. To perceive a dog (a fox, a wolf, a jackal) for a

[1] I am obviously drawing here an analogy to Nagels's well known essay "*What Is It Like to Be a Bat*" (Nagel, 1974).

rabbit means that there is a kind of negative feedback, a program in its brain telling *escape*! The rabbit is not simply adapted to its world (that includes dangerous predators), but is able to develop a particular *scheme of reaction* to different objects in its environment.

Here we have to keep in mind that many traditional biological conceptions somehow give the impression that organisms are passive objects shaped by their surroundings. In its hard-core version, the synthetic theory of evolution is an adaptationist program that conceives of organisms as objects exclusively influenced and formed by external selection.

3.1. Organisms as Active Systems: Internal Factors in Evolution

On the other hand, it seems quite trivial that living beings are anything else but passive. They run, fly, swim, dig, build nests and so on and so forth. They are not just influenced by their respective environment(s), but they themselves have a significant effect upon their surroundings. "*Organisms are*", as Weiss (1969: 362) put it, "*not puppets operated by environmental strings.*" Or, as Bertalanffy (1952: 129) said: "*A living organism is a hierarchical order of open systems which maintains itself in the exchange of components by virtue of its system conditions.*" Thus, in a nutshell, organisms are not determined by their environment(s).

For this reason, many biologists—and philosophers of biology—have claimed that what is needed is an *organism-centered* view describing and explaining the important (active) role of organisms in their own development and evolution. "*Organisms inherit a body form and a style of embryonic development; these impose constraints upon future change and adaptation. In many cases, evolutionary pathways reflect inherited patterns more than current environmental demands*" (Gould, 1983: 156).

Organisms are complex and highly organized systems that contain an enormous number of interacting elements at different levels of their organization:

> Viewed at any level, from organ and tissue down to cell and component molecules, the organism is a highly ordered system. This is true both of structures and of processes. The macroscopic organs and their functions fit together. Similarly the basic structures, such as the chromosomes, form a coherent pattern and undergo collective motions and transformations displaying a high degree of spatial and temporal coordination. This coordination is pervasive at all levels. The ultra-structure of the living cell is an intricate differentiated network undergoing global pulsations and transformations under some law of ordering which preserves the unity of the system. (Whyte, 1965: 19)

A systemic or systems-theoretical approach to evolution (see, e.g., Riedl, 1977; Wagner, 1985; Wuketits, 1988) takes cognizance of this *inner order* of living beings and stresses the importance of internal selection. There is of course nothing mystical about this type of selection, and it must not be confused with life forces assumed by vitalists (*élan vital* and things like that). As hierarchically organized open systems living beings consist of parts that are mutually linked together by feedback loops and regulatory principles. Any organism is a multilevel system; not only its parts or elements determine the whole system, but the organism vice versa determines and constrains the structure of its parts in what Campbell (1974b) called *downward causation*. Hence, there is a constant flux of cause and effect in two directions. Internal selection, then, means that the construction or *Bauplan* of an organism constrains its own evolution and adaptation. Adaptation can be regarded as an external affair, so to speak, but *adaptability* is defined by the organism itself.

Besides, as any biologist will admit, there are—anatomical, behavioral—traits in many species that can hardly be explained as adaptations, this is to say characters not built by selection for their current roles but evolved for other usages. Examples are given by Gould and Vrba (1982) who introduced the term *exaptation* for such phenomena. In short, environmental selection and adaptation are crucial in evolution, but they are not everything! Sure, *" [. . .] adaptationist storytelling continues to be a powerful method for the discovery of important facts about living organisms*" (Williams, 1996: 19), but we should not ignore other stories that might be powerful as well.

It is obviously not well known that Darwin himself argued along similar lines and was not at all a strict selectionist and adaptationist (see Wuketits, 2000a). Consider the following passage in the *Origin*:

> Naturalists continuously refer to external conditions, such as climate, food, etc., as the only possible source of variation. In one limited sense [. . .] this may be true; but it is preposterous to attribute to mere external conditions, the structure, for instance, of the woodpecker, with its feet, tail, back, and tongue, so admirably adapted to catch insects under the back of trees. (Darwin, 1958: 28)

Since living systems are not puppets operated by environmental strings, we also have to state that their respective cognitive apparatus is not a passive organ simply waiting for impressions they get from outside. Thus, we attain a non-adaptationist view of cognition and knowledge and a non-adaptationist version of evolutionary epistemology (see also Wuketits, 1989, 1990, 1997, 2000b) which is mainly based on the following assumptions:

(1) Cognition is the function of active bio-systems and not of blind machines that just respond to the outer world.

(2) Cognition is not a reaction to the outer world but results from complex interactions between the organism and its surroundings.
(3) Cognition is not a linear process of step-by-step accumulation of information but a complex process of continuous error elimination.

Needless to say that the last point strongly resembles Popper's views of evolutionary epistemology and scientific methodology. In fact, Popper is to be regarded as one of the founders of evolutionary epistemology and advanced the selective elimination model (see Campbell, 1974a).

3.2. Coherence

Yet, in our everyday life—and according to our common sense—it seems plausible that our perceiving apparatus, and the perceiving apparatus of other animals as well, *corresponds* to the outer world. From our everyday perspective stones are really stones, trees are really trees, wine-glasses are really wine-glasses and so on and so forth. Well, but what else should these objects be, if not stones, trees, wine-glasses, etc.? This, however, is not the point. In our everyday life we may believe that all (perceived) things are as they appear to be. What counts is that our perceptions help us to survive. (Remember the rabbit perceiving a dog.) Thus, at the epistemological level the notion of correspondence has to be replaced by the notion of coherence.

But epistemology is supported by evolution and evolutionary biology. The central problem is survival. Thus, "*[...] reality rests ultimately on a sense of coherence and success—consiliences, and the like, really do work*" (Ruse, 1986: 191). In other words:

> Evolutionary epistemology pictures the intellect as pre-adapted to the reality with which it must cope. This is no mysterious acausal process. Rather it is just that many causal chains leading to general forms of knowledge are terminated before the individual is born. Causal forces, acting on a genetic level, render knowledge which is individually a priori empirically respectable. Selective pressures produce . . . a "benign inner environment". One, that is, appropriate to the external world which edits (by death and failure to reproduce) the range of permissible representations and dispositions. (Clark, 1983: 28–29)

The notion *pre-adapted* might be misleading, but what is meant here generally is that for any organism's ultimate goal is genetic survival, the organism has to generate a *life-supporting* view of the world it lives in. "*Sight of prey or sound of predator must be suitably processed or interpreted to result in use of teeth or use of feet accordingly.*" (Clark, 1986: 151). Similarly, Popper (1972: 145) already argued that:

> [Sense organs] incorporate . . . theory-like expectations. Sense organs, such as the eye, are prepared to react to certain selected environmental events—to those events which they 'expect', and *only* to those events. Like theories (and prejudices) they will in general be blind to others: to those which they do not understand, which they cannot interpret (because they do not correspond to any specific problem which the organism is trying to solve).

Thus, Simpson's monkey is not forced to reflect upon something like a *tree branch-in-itself*, but it has to conceive of the tree branch in a life preserving way. Anyway, monkeys are not compelled to solve any philosophical problem, however, as arboreal animals they must react adequately to trees and their branches. To give another, somehow drastic example, the idea that sitting on a (hot) stove can cause a nice orgasm will not at all help survival, but lead just to the opposite (and the awaited orgasm will of course never come). We have good reasons to believe that all animals—if there were any—that created this idea are no longer around. They were eliminated by natural selection.

The notion of coherence of course does not mean that organisms are autonomous beings and totally independent of their environment(s). Sure, each species has its own way of living and, thus, its own mode of perceiving and coping with its external world. This was already pointed out by Uexküll (1928) who postulated that each species lives in—and shows its—own *ambient*. The mode of its perceiving the outer world is determined by its specific type of organization. Compare, for instance, the organization of sea urchins, bats, and dogs. An example to which evolutionary epistemologists frequently refer is a tick's perception of mammals. Ticks are quite unpleasant, blood-sucking parasites that also attack humans (and can cause serious diseases). How does a tick know, so to speak, whether an object is a suitable host? From the point of view of a tick, a mammal is essentially characterized by a body temperature of approximately 37°C and the odor of butyric acid emanated by any mammalian species. In other words, the perceiving apparatus of a tick reduces mammals to only two characteristics. Imagine a zoology student who does not know more about mammals! But the tick studies mammals only for its own specific purpose, and its knowledge that a host shows these two characteristics is most sufficient for the sake of survival. At the same time, a tick's organization does not allow much more.

Organization, however, generally requires coherence, that means, all parts of any living system—at its different levels—must be linked together in a somehow harmonious way (see above). Certainly, this organism's coherence, as manifested in anatomical composition as well as in functional properties (including cognitive capacities), is connected with the requirements of the respective external world with which the organism builds a feedback cycle (see also Riedl, 1987; Wuketits, 1990). A non-adaptationist approach to evolution and cognition, then, of course should not be confused with an *antiadaptationist* view.

All this brings us now to one of the most serious and venerable philosophical problems.

4. REALITY AND REALISM

"*In daily life*", said Russell (1967: 1), "*we assume as certain many things which, on a closer scrutiny, are found to be so full of apparent contradictions that only a great amount of thought enables us to know what it is that we really may believe.*"

The problem of reality has concerned—and divided—philosophers for many centuries. What is *reality*? Is there something like *ultimate reality*? How *real* is what appears to be real? Do we, after all, live in a world of illusions? This is not the place to discuss realism in its many aspects and ramifications (see on this, e.g., Oeser, 1988b; Putnam, 1987). Rather, a solution of the problem of reality from the point of view of the non-adaptationist approach in evolutionary epistemology is attempted (see also Wuketits, 2000a, 2000b). However, what follows cannot be more than a brief outline of such a solution.

From what I already said we can conclude that organisms do not simply get a *picture* of (parts of) the world, but rather develop a particular way to react to what is happening *outside*. Whenever an organism perceives something, it immediately *interprets* what it perceives (sees, hears, smells, etc.). My notion of reality and realism is a functional one, and this means that when for example we humans perceive any object, we do so since all objects—as far as they can be perceived by us at all—show certain properties or have certain functions *for us*. This resembles Oeser's notion of *functional coherence* (Oeser, 1988a).

The supposed correspondence or congruence between the objective world and a perceiving subject

object $\approx$ subject

has to be replaced by a broader view expressing the close phylogenetic relations between object and subject and showing that they interact and are parts of *one* reality:

[object $\leftrightarrow$ subject].

However, different animals are endowed with different sense-organs or, as is the case in protozoans, particular organelles that perform similar functions at a lower level (a famous example is the paramecium and its avoiding reaction).

But even among the members of one and the same species, the perceiving apparatus can be developed in different ways. Let us take, for example, color vision and remember that many humans are red–green color-blind (see, e.g., Dennett, 1991). *Red* and *green* are properties that for those people have no meaning or, at least, are not the same as for other people. And we should also keep in mind that many animals—among them our pets, cats and dogs—are not equipped with color vision at all. The question: *Is the world perceived by a 'normal' (not color-blind) human being truer than the world perceived by color-blind people or dogs, cats, etc.?* does not make much sense. For what counts is survival, and nothing more. There are different types of eyes or, more generally, photoreceptors, and, therefore, various ways to perceive different objects of the world. None of them is better than others, and none of them offers the very truth about this world. What counts is that its mode of perceiving (parts of) the world helps the respective organism to solve, for survival's sake, its problems.

Thus, again, it is not necessary that the perceived objects *in here* correspond to the objects *out there*.

Sjölander (1995) uses the following metaphor which is quite accurate in this context. In an orchestra, the players (as active organisms) are playing according to given notes (inputs from the sense-organs). Although the musicians pay attention to the notes they are not acting like puppets operated by the music book. Their playing is a self-governing activity, not created by the notes. The notes even do not give sufficient information about how to make music. To complete this metaphor with regard to the above example, we can say that like any successful musician who is able to find his/her own style of playing music (and not just to read notes), any successful rabbit has found its way to escape from dogs (and not just learned to recognize dogs and to obtain a *realistic perception* of these predators).

From the point of view of survival, some of our conceptions of the outer world are simply better than others although they do not necessarily tell us something about reality as it actually is. This has some—astonishing (?)—implications for philosophy of science. As Ruse (1989: 193) puts it:

> We believe that $2 + 2 = 4$, not because it is a reflection of absolute reality, or because some of our ancestors made a pact to believe in it, but because those proto-humans who believed in $2 + 2 = 4$, rather than $2 + 2 = 5$, survived and reproduced, and those who did not, did not. Today, it is these same selectively produced techniques and rules which govern the production of science [. . .] Although science reaches up into the highest dimensions of culture, its feet remain firmly noted in evolutionary biology.

And so do, as I should like to add, all the other of our *feet*. We humans are *realists* in a most specific sense. Even the belief in a kind of absolute or ultimate reality—whatever this is supposed to be—is part of our nature and, under particular circumstances, might help us to survive. However, such a belief does not tell us anything *true* about the supposed ultimate reality.

In the tradition of Western philosophy we are accustomed to believe that there are knowledge systems which are somehow superior to anything else that evolution has brought forth and are even free, so to speak, from any biological imperative (survival!). An example for such systems is logic, a system of propositions and of their use in argumentation. However, as Cooper (2001) shows, from an evolutionary point of view logic is not purely analytic but empirical, and not absolutely valid but only relative to specific population processes. In other words, it has not its 'own reality' but is influenced by evolutionary constraints.

This view of reality has at least two important—philosophical, epistemological—implications. *First*, organisms do not simply get a picture of (parts of) reality, but develop, as was already hinted at, a particular *scheme of reaction*. In the moment an organism perceives an object of whatever kind—and even if it just imagines that it has perceived a particular object—it immediately begins to *interpret* this object in order to react properly to it.

Second, the notion of a world-in-itself becomes obsolete or at least redundant. What counts for any organism is that it copes with its *own world* properly. A tick will never have our knowledge capacities, but it *knows* as much of its own world as we do about ours.

Living systems are cognitive, learning systems (Lorenz, 1977). If this is true—and there is no evidence that it is not true—then "[. . .] *because, within given environmental limits, they perfectly know how to transform external [. . .] information into coherent internal structures*" (Heschl, 1997: 112). Maybe they do not know *perfectly*, but they usually know how to transform the information in order to survive. Some do not know, but they do not play any role in the stream of life.

Does, then, evolutionary epistemology in its non-adaptationist version support constructivism? In a way it does. (See on this Diettrich, 2003, this volume; Irrgang, 2001; Riegler, this volume). We have to recognize that cognition is not just a process of reconstruction (of what is *out there*), but that it always includes construction (by means of what is *in here*). However, advocates of what is called *radical constructivism* will hardly find support by this version of evolutionary epistemology. For what counts is, again, survival, and any organism that would totally neglect the outer world and rely exclusively on its own constructions would not survive. Simpson's monkey is not forced to know what a tree branch is after all, but it is definitely forced to recognize that there is something *out there* which does not exist only in its own imagination.

It is understandable that a philosopher whose thinking is deeply rooted in (some kinds of) idealism and who, therefore, tends to believe in an absolute reality will be disappointed by the approach presented here. But time has come to squarely face the ultimate consequences of evolutionary thinking and thus to realize that our images of reality rest on life and survival. There are no first principles on which we could rely; we have only our own experiences in our lives that, however, are based on experiences of millions of generations who lived before us—and survived because they did not get it entirely wrong. After all, the belief in any kind of external reality has most probably been adaptive and helped survival (Stewart-Williams, 2003).

5. CONCLUSION

From this rather sketchy treatment of some aspects of evolutionary epistemology and its non-adaptationist approach we can derive at least four general conclusions that are of great importance for philosophy. In fact, they contradict some long-standing traditions in Western philosophy.

First, the notion of *idea* in the sense of Plato—Plato's essentialism—has become definitely obsolete. No one who takes evolution and, consequently, evolutionary epistemology really seriously, can believe that there is something like *essence* beyond each object of this world. Evolutionary thinking contradicts essentialism or typological thinking for the latter "*is unable to accommodate variation*" (Mayr, 2000: 82). And what is most important in evolution, is variation, and not a *fixed* type.

Second, notions of the *absolute—absolute knowledge, absolute truth*, etc.—have to be abandoned. In particular, the lasting attraction of (absolute) truth becomes apparent even in the work of philosophers like Popper, an *anti-essentialist* whom evolutionary epistemology owes a lot. However, when Sir Karl pointed to an ever-better approximation (of theories) to truth (Popper, 1972), what else did he keep in mind if not the idea that there is something like the truth-in-itself (?). But, to put it bluntly, let us forget about it. *Truth* has much to do with evolutionary fitness. It is a typically human construction and has the function to give us some security in a generally insecure and unpredictable universe.

Third, there is no need for the belief in the *unknowable*—and thus no need to assume the existence of an unknowable *world-in-itself*. If we take evolutionary epistemology really seriously—and here it even does not matter, whether we take an adaptationist or a non-adaptationist stance—then it is quite obvious that a notion to which an organism cannot refer in its *real life* is useless.

Forth and finally, the belief in *absolute values* has to be dismissed. Humans act in—and according to—changing environments, values are their own constructions and nothing a priori given. Values change as our living conditions change. Values are useful in any given context of human social life, but not outside of any contexts. Yet as the contexts change, values are relative, if not biologically, then with regard to changing social and cultural requirements. But this is already another topic (evolutionary ethics).

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Like cats and dogs: Radical constructivism and evolutionary epistemology

Alexander Riegler

Center Leo Apostel for Interdisciplinary Research
Vrije Universiteit Brussel, Brussels, Belgium
ariegler@vub.ac.be

Abstract

I identify two similarities between evolutionary epistemology (EE) and radical constructivism (RC): (1) They were founded primarily by biologists and (2) their respective claims can be related to Kant. Despite this fact there seems to be an abyss between them. I present an attempt to reconcile this gap and characterize EE as the approach that focuses on external behaviour, while RC emphasizes the perspective from within. The central concept of hypothetical realism is criticized as unnecessarily narrowing down the scope of EE. Finally, methodological and philosophical conclusions are drawn.

1. INTRODUCTION

In 1912, philosopher Bertrand Russell wrote: "*There is no logical impossibility in the supposition that the whole of life is a dream, in which we ourselves create all the objects that come before us. But although this is not logically impossible, there is no reason whatever to suppose that it is true*" (Russell, 1912: 35). Almost 90 years later, neurophysiologist Rudolfo Llinás seemed to contradict Russell's view. He argued that the mind is primarily a self-activating system, "*one whose organization is geared toward the generation of intrinsic images*" (Llinás, 2001: 57) and this makes us "*dreaming machines that construct virtual models*" (Llinás, 2001: 94).

In some sense these statements could be considered the respective epistemological mottos of evolutionary epistemology (EE)[1] and radical constructivism

[1] In the present context EE refers to evolutionary epistemology of mechanisms rather than evolutionary epistemology of theories—the classical distinction proposed by Michael Bradie (1986).

N. Gontier et al. (eds.), Evolutionary Epistemology, Language and Culture, 47–65.

(RC).[2] The former focuses on the *observation* of *external* entities, the latter concentrates on system-internal mechanisms (including an account for the activity of *observing*).

The paper starts with the observation that both disciplines are mainly supported by biologists and based on insights from ethology, biological morphology, neurophysiology and evolutionary theory. Despite the common roots (or because of them?) their mutual relationship seems to be dominated by animosities. I will outline the basic ideas that define (and separate) EE and RC in order to provide some answers to the question which of them is the 'correct' perspective. Steps towards a reconciling view have been taken by other authors, for example by Franz Wuketits (1992) and Sverre Sjölander (1997), whose respective interpretations of RC from an EE point of view seem to make the discrepancies disappear. However, there are reasons to assume that their understanding of RC is biased by their support for EE. Therefore, I will attempt a re-interpretation of one of the central notions of EE, *hypothetical realism*, from a RC perspective in order to assess their respective scientific value (and compatibility) for understanding cognitive systems.

Based on the analysis my conclusions will be twofold. From a methodological point of view, it appears possible to bridge the abyss between RC and EE. From a philosophical-linguistic perspective, however, they do not explain cognition equally well.

2. HOW TO APPROACH COGNITION

How can we account for cognition? As living beings we perceive a 'reality' full of different modalities and engage in a variety of actions. These impressions and experiences do not seem to come in chaotic disorder. Using our cognitive abilities, we make sense of the world. We can identify objects and distinguish them from one another. Also, we can manipulate entities in our reality, thus changing their configuration to meet our needs. All this seems rather self-evident and trivial to us. However, we did not possess this range of faculties at the time of our birth. Hence, there is an ongoing (and actually never-ending) process of cognitive development, which makes us what we are.

Similar observations apply to other *biological* entities, i.e., animals, as well. From their display of non-random behaviour we conclude—either as animal owner or professional ethologist—that they too do not just experience a chaotic disorder of colour and noise. Quite on the contrary, some reveal remarkable capabilities. However, there are differences. For example, it is hard

[2] Including Maturana's *Biology of Cognition* (e.g., Maturana, 1970; see also below) and Foerster's *Second Order Cybernetics* (e.g., Foerster, 1974).

to attribute human language capabilities to (most of) animals, and probably all fail to solve mathematical equations. Despite the gradual difference between humans and dogs, between cats and amoebas, one thing they all have in common is the ability to cope with their environment using their cognitive abilities. The complexity of ognition,[3] e.g., measured in terms of behavioural repertoire, is different for different individuals: There is a large-scale between zero cognition (non-living matter) and human-like cognition. If we trust in the idea of *biological* evolution (rather than creation) we have to ask for the mechanisms that have evolved the wide range of different cognitive apparatus over time.

Both EE and RC set out to provide a naturalized account for cognition, and both refer to biology as the starting point of their consideration. Constructivist Heinz von Foerster (1984: 258), for example, prophesies that "*in the last quarter of [the 20th] century biologists will force a revision of the basic notions that govern science itself.*" Evolutionary epistemologist Wuketits claims that biological evolution can be extended far beyond its original scope: "*Since the human mind is a product of evolution—any opposite view such as that of classical dualism means a kind of 'obscurantism'—the evolutionary approach can be extended to the* products of mind*, that is to say to epistemic activities such as* science" (Wuketits, 1984: 8).

Therefore, EE and RC could be labelled competitive *research programmes* for studying the phenomenon of cognition. In a nutshell, the research programme of EE is intended to understand the evolution *of* cognition. It is based on a 'life is cognition' conception. Cognition is considered the result of exogenous factors such as evolution and environmental influences. In other words, EE is concerned about the *observation* of systems in order to derive insights about the observed systems.

While the constructivist programme, too, favours a 'life is cognition' approach, it differs significantly from EE by drawing attention to the process of *observing* rather than putting up with the *observed*. It contends that the real world consists of *what matters* instead of saying it consists of *matter*. Humberto Maturana (1978: 31) wrapped this starting point into his well-known statement "*Everything said is said by an observer.*" In other words, RC is the concept that individuals construct[4] their own realities whereby the observation

[3] It is important to note the difference between *cognition* and *intelligence*: Cognition is defined as the process of living, i.e., the interaction between an organism and its environment with relevance to the maintenance of itself. Intelligence, on the other hand, is considered as the capability of rational problem-solving (the domain in which artificial intelligence systems are supposed to excel).

[4] The term *construction* refers to the process by which complex structures are assembled from building blocks. RC assumes that there are generally applicable construction rules which are independent from the ontological nature of both the atomic components and the assembled

process cannot be separated from the observer. As a result, it emphasizes the internal perspective rather than the output point of view an observer is necessarily focussed on.

Let us have a closer look at both disciplines.

2.1. *Evolutionary Epistemology*

EE starts from the understanding that studying the evolution of the cognitive capacities of biological systems leads to an understanding of its functions, i.e., the cognitive processes that are responsible for the gain in knowledge an organism uses to survive in a dynamic world. Basic to its definition are early works such as Konrad Lorenz (1941/1982), Donald Campbell (1974), Gerhard Vollmer (1975/1987) and Rupert Riedl (1979/1984). It presents itself as a natural history or biology of cognition.

The evolutionists' approach is based on theories of evolution of behaviour in which cognitive processes play an important role. Such a *Darwinian epistemology* (Wuketits, 1991) starts from the paradigm of natural selection, which was traditionally been inseparably connected to the concept of adaptation. The emphasis on adaptation as an inevitable reaction process to a changing environment, including all structures and functions of the selective units, has been severely criticized for the conception that organisms passively react to their environments. This view goes back to Lorenz's 1941 publication where he wrote that the horse's hoof is a representation (*Abbild*)[5] of the steppe, the body form of the dolphin is the incarnation of knowledge about laws of hydrodynamics in water, etc.[6] Although the adaptive element of the evolution of cognition remains a key part of the evolutionary approach, its theoretical status has changed in the direction of a less restrictive interpretation. Eve-Marie Engels (1989) suggests refraining from adaptationism as the foundation for

complex structure, respectively. From a realist perspective cognitive representations are constructed out of objective facts, whereas constructivists maintain that representations are constructed out of simpler cognitive components.

5 Space does not allow for a more detailed discussion of the (problematic) notion of representation. The classical *referential* theory of representation assumes a homomorphic mapping from structures of a mind-independent reality onto structures of the cognitive apparatus, i.e., subjectively experienced reality W is a function of the 'outer' reality R, $W = f(R)$. However, this naïve conception has been attacked by many authors (for details, see Riegler et al., 1999).

6 "*Our categories and forms of perception, fixed prior to individual experience, are adapted to the external world for exactly the same reasons as the hoof of the horse is already adapted to the ground of the steppe before the horse is born and the fin of the fish is adapted to the water before the fish hatches*" (Lorenz, 1941/1982: 124–125). Lorenz (1973/1977: 23) states that *"an image of the material world is built up within the organism [...] a photographic negative of reality...*"

an evolutionary explanation of cognition. She argues in favour of a broader view on evolution within which organisms are interpreted as active systems, which do not just represent or reconstruct an external reality by applying their cognitive apparatus. So while adaptationism plays an important role in evolution, it is no longer considered to explain everything. Lorenz's example of the hoof depicting the hard steppe it runs on is valid as long as it is regarded a metaphor of the fact that the horse, by developing hoofs, has solved the problem of how to cope with the steppe (Oeser, 1987). Similarly, it does not make sense to claim that birds fly 'better' than bats or insects.

So why not extend the notion of cognition to cover more than just the *adaptive* side of behaviour? Several authors emphasized the tight relationship between life and cognition, and agree to this simple equation *Life = Cognition*, which puts the accent on the inseparable linkage between cognition and life. "*Living systems are cognitive systems, and living as a process is a process of cognition*", wrote Humberto Maturana and Francisco Varela (1980: 13). Adolf Heschl (1990: 18) claimed that both terms "*... are revealed as truly synonymous notions*". To view life itself as a knowledge-gaining process[7] is not only useful for metaphorical reasons, but has its merits in directing attention to the understanding of cognition as a bio-function which is necessary to guarantee, or even improve, the fitness of living systems. In other words, *the prototypical form of knowledge is knowing how to stay alive* (cf. Stewart, 1991, 1996).

2.2. Radical Constructivism

In contrast to the environmentally oriented view described in the previous section, the constructivist perspective emphasizes the autonomous role of the cognitive system. By proposing a non-adaptationist view, it suggests that the output of cognition is mainly a function of the cognitive system itself, especially of its self-organizing and constructive activities. Here, the active role of the organism is stressed, and the direction of causation has been reversed in favour of a subject-centred perspective: the organism itself influences its environment.

Putting the stress on being the discipline that sees things *from within*, RC expresses the insight that experiences are all we have to work with, that out of experiences we construct what appears to us as 'world', and that "*we cannot transcend the horizon of our experiences*" (Riegler, 2001b: 1). A way to understand the constructive elements included in cognitive phenomena is illuminated by *cognitive constructivism*, a programme that is strongly intertwined

[7] Cf. also Lorenz's well known dictum *"Life itself is a process of acquiring knowledge."*

with the work of Jean Piaget's *genetic epistemology* (e.g., Piaget, 1937/1954). This psycho-ontogenetic position contributes to the synthesis of self-organizing and adapting elements in the course of the individual's cognitive life by introducing the concepts of assimilation and accommodation as functional conditions for the cognitive process. It stresses the importance of the cognitive development of human beings, i.e., the ontogenetic evolution. Cognition must not be seen as static ability but rather as a dynamic process that has its origin in the sensorimotor stage of early childhood. Following Piaget's insights, Ernst von Glasersfeld (1991) claims that knowledge is not passively received but actively built up by the cognizing subject. Furthermore the function of cognition is adaptive; it serves the organization of the experiential world, not the discovery of ontological reality.

Maturana and Varela (1980) have developed their constructivist theory by taking for granted that living systems are cognitive systems defined by their *self-referring* organization. Being organizationally closed these systems are autonomous.[8] In other words, RC draws attention to the point that cognition in general and knowledge about the 'world' in particular must not be viewed as a mapping of features of an external world but rather as the ability to act appropriately in the environment.

3. COMPARING EE AND RC

As we have seen above, both disciplines set out to provide a naturalized account of cognition, and both refer to biology as the starting point of their consideration. Further similarities can also be detected among their respective proponents as well as their philosophical heritage.

3.1. The Proponents

In 1957, Foerster founded an interdisciplinary laboratory at the University of Illinois. Inspired by the emerging discipline of cybernetics in the late 1940s and early 1950s he called it the *Biological Computing Lab* (Müller, 2000). As the subtitle of their annual transactions (Pias, 2003) announced, cyberneticians focussed on circular-causal and feedback mechanisms *in* biological and social systems. Another proponent of RC, Maturana, made a career in neurophysiology where he first investigated the eye–brain connection *in* frogs (Lettvin et al., 1959). Later his attempts failed to investigate whether the *spectral composition*

[8] For an application of closure to cultural contexts, see Liane Gabora (2000).

of colours correlates with the activities in the retina of pigeons. What he found instead was that the activity of the retina can be connected to the *names* of colours, which are considered to be rough indicators of how colours are *subjectively* experienced (Maturanaet al., 1968). Maturana's astonishing conclusions were that the objective of his research had turned to comparing "*the activity of the nervous system with the activity of the nervous system*" rather than with an external reality (quoted in Pörksen, 2004: 61). The theoretical framework he developed from his experimental research is called *Biology of Cognition* (Maturana, 1970). Finally, Gerhard Roth's constructivism (e.g., Roth, 1994) arrives from the perspective of 'cognitive neurobiology'. Starting from neurophysiological insights, his goal was to formulate rules for the construction of reality *in* the brain.

In the EE camp, Lorenz was a famous ethnologist, whose groundbreaking studies of the *behaviour* of geese made him world-famous (e.g., Lorenz and Tinbergen, 1939). In 1973, he won the Nobel Prize for his studies of human and animal behaviour. In particular, Lorenz investigated imprinting and instinct behaviour of animals, the release mechanism that responds to key stimuli, fixed action patterns which serve as the foundation of the study of animal behaviour, as well as the phylogenetic development of innate behaviour.The starting point for his student, marine biologist Riedl was morphology, which deals with the *forms* and *shapes* of organisms or parts thereof. Soon he turned to his second passion, the biological-philosophical roots of knowledge, in particular to the study of homologies, which explains the structural similarity between different species in terms of shared ancestry. His 1979 book carries the name *Biology of Knowledge*, in which he argues in favour of evolution as a knowledge-acquiring process propelled by adaptation through which the laws of nature can be extracted. It is interesting to note the apparent similarity between Maturana's and Riedl's book. The former, however, refers to the dynamical process of cognition, the latter to the static quality of knowledge.

The observations presented in this section suggest that RC proponents have developed a preference for looking at the mechanisms *inside* systems, i.e., they are interested in the *inner* perspective. In contrast, supporters of EE emphasize observing behavioural patterns, i.e., they are interested in the *outside* view. They observe behaviour and postulate a link between their rule-like behaviour and general laws of cognition and (phylogenetic) knowledge acquisition. Whether being ethologists or morphologists, the focus of attention is the *output* of the observed system, which they map onto their own experiential network. Behaviours are anthropomorphically *attributed* (Sjölander, 1997).[9] However, an observer is not necessarily embodied in the world of the observed animal (Nagel, 1974; Riegler, 2002). Rather she interprets its behaviour within her own referential system of understanding. This reminds us to Richard Feynman's (1985) cargo cult science criticism, an analogy where islanders tried to replicate the *shape* of Western technology (an airport) with wooden models simply because primitive mechanical models were *their* referential system, the only one they had access to. Consequently, the inner working of a genuine airport completely escaped their intellectual capacities. For EE this means that even if we had the intellectual capacity to make inferences from the appearance to the inner working, we would face a huge number of possible mappings from observational data onto the model. There is a sheer astronomical number of ways to explain data points (McAllister, 2003). Facing this intellectual problem, all we can do is *trivialize* complex systems (Foerster, 1972). That is, we reduce the degrees of freedom of a given complex entity to behave like a trivial machine, i.e., an automaton that maps input directly on output without recurring to internal states.

Ultimately, the gap between EE and RC can be considered a typical instantiation of what Valentin Braitenberg (1984) called the *law of uphill analysis and downhill synthesis* with EE trying to analyze (the complexity of) observed systems and RC synthesizing their complex psychological behaviour in terms of simple rules at a low level. Even though 'non-armchair' radical constructivists such as Maturana and Roth started as *observing* biologists (like many proponents in the EE camp), they later turned their attention to the individual's *input* perspective. As mentioned above, in Maturana's concept of autopoiesis[10] the crucial aspect is that of self-reference: Not the output defines autopoietic (i.e., living) systems. Rather they perform a certain output in order to control their input state such as state of hunger, and other crucial parameters (cf. also Porr and Wörgötter, 2005). Therefore, modelling living systems—as a procedure to trivialize complex systems in the above sense—must be considered as turning autopoietic machines into allopoietic ones, i.e., as opening their fundamental closure with respect to the modeller. Maturana notes that

[9] Cf. also Foerster (1970, 2003: 169) who characterized "*anthropomorphizations*" as "*projecting the image of ourselves into things or functions of things in the outside world* ".

[10] According to Maturana (1970, 1974, 1978, 1988; Maturana and Varela, 1980), autopoietic systems are a subset of self-organizing systems that obey the following criteria: (1) The components of autopoietic systems take part in the recursive production of the network of production of components that produced those components. (2) An entity exists in the space within which the components exist by determining the topology of the network of processes. A system that does not fulfil these criteria is called allopoietic, e.g., machines that serve a different purpose than maintaining their own organization.

> [. . .] an observer may treat an autopoietic system as if it were an allopoietic one by considering the perturbing agent as input and the changes that the organism undergoes while maintaining its autopoiesis as output. This treatment, however, disregards the organization that defines the organism as a unity by putting it in a context in which a part of it can be defined as an allopoietic subsystem by specifying in it input and output relations. (Maturana, 1974: 468)

We have to conclude that observed behaviour, i.e., a protocol of inputs and outputs, cannot capture the essence of a living organism.

3.2. The Heritage of Immanuel Kant?

It is interesting that both EE and RC can also be traced back to Immanuel Kant. Lorenz (1941/1982) naturalized Immanuel Kant's (1781) a priori of space and time, which Kant regarded indispensable for understanding raw sensory experience, and re-interpreted them as phylogenetically acquired categories. According to Lorenz, EE is the world of the paramecium and "*barbarian seal hunters*" (see below). The evolutionarily acquired *Denk- und Anschauungsformen* do not distort our view on reality in itself but rather deliver a true albeit simplified picture.

> We have developed 'organs' only for those aspects of reality of which, in the interest of survival, it was imperative for our species to take account, so that selection pressure produced this particular cognitive apparatus . . . [W]e must assume that reality [*das An-sich-Bestehende*] also has many other aspects which are not vital for us, barbaric seal hunters that we are, to know, and for which we have no 'organ', because we have not been compelled in the course of our evolution to develop means of adapting to them. (Lorenz, 1973/1977: 7)

He called these inborn structures *innate teaching mechanisms* [*Angeborene Lehrmeister*]: "*These mechanisms also meet the Kantian definition of a priori: they were there before all learning, and must be there in order for learning to be possible"* (Lorenz, 1973, 1977: 89). Following Egon Brunswick (1955), Riedl (1979) speaks of the *ratiomorphic apparatus*. That is, human beings feature a system of *innate* forms of ideations that allows the anticipation of space, time, comparability, causality, finality, and a form of subjective probability or propensity (Riedl et al., 1992). In this sense, from the perspective of EE biological insights support the Kantian a priori of individual cognition.

For RC, Kant's *Copernican Turn* can be identified as a motivational stepping-stone. Kant (1781: Bxvi) argued that so far "*it has been assumed that* *all our knowledge must conform to objects*"—an approach that he regarded a failure. Instead he proposed a 'Copernican Turn', according to which "*objects must conform to our knowledge*" (ibid.) (rather than the other way around), thus radically dismissing any form of determinism of the cognizing individual through the outside reality (see also Bettoni, 1997). In order to implement the Copernican Turn we refer to what Foerster called the *principle of undifferentiated encoding*. It was first formulated in the late 19th century and applies ubiquitously in the nervous system: *"The response of a nerve cell does not encode the physical nature of the agents that caused its response. Encoded is only 'how much' at this point on my body, but not 'what'"* (Foerster, 1973: 214–215). Maturana and Varela enlarged this argument to what they call the *organizational closure* of the nervous system, which is *"a closed network of interacting neurons such that any change in the state of relative activity of a collection of neurons leads to a change in the state of relative activity of other or the same collection of neurons*" (Winograd and Flores, 1986: 42). Therefore, the cognitive apparatus necessarily constructs its reality and the entities it is populated with in the first place. Perturbations from the outside may, at best, modulate the dynamical construction process of the cognitive apparatus but not determine it. There is no purpose attached to this dynamics, no goals imposed from the outside relative to the cognitive apparatus. In other words, the cognitive apparatus predetermines what to perceive thus implementing Kant's Copernican Turn: Objects conform to the cognitive apparatus. Its dynamics follows the *constructivist-anticipatory principle* (Riegler, 1994): The mind constructs cognitive structures in the first place and seeks occasionally to validate them through sensory input. Riegler (2001a) compares this with a relay race where the runners focus on their running except for the short moments of coordination when they pass the baton on to the next runner. One could describe the moments of coordination as *checkpoints* (Riegler, 1994) where the runner verifies that he is still on track such that the race can go on with the subsequent team member. Oliver Sacks's (1995) example of a blind man demonstrates that humans rely on such relay race-like cognitive strategies. The man recognized things by feeling their surface in a particular order. When walking through a familiar place he did not get lost because he relied on a certain sequence of tactile impressions he would encounter. This applies to visual perception as well. For Kevin O'Regan and Alva Noë (2001) *seeing is knowing sensorimotor dependencies*, and the brain is a device to extract algebraic structures between perception and action (rather than from the world). All these constructivist concepts support the Kantian idea of the mind commanding reality.

3.3. *The Controversy*

Sadly though, despite their identical starting points and goals EE and RC do not go well together. Glasersfeld (1985), for example, points out that one of EE's central notion, adaptation, even in the weaker sense as described above, is meaningless. For him, Popper's (1963) rejection of instrumentalism (a cornerstone of RC) on the basis of its inability *to account for the pure scientist's interest in truth and falsity* is unacceptable polemics. Riedl, on the other hand, is eager to dismiss RC as a solipsistic school. In his favourite thought experiment the sudden appearance of a rhino at a congress of constructivists teaches them that reality does exist. His aversion to the constructivist worldview springs from Lorenz' motto "*To believe plain nonsense is a privilege of the human being*" (quoted in Riedl, 1979: 34). It expresses the conviction that organisms that do not 'believe' in a mind-independent reality will be eradicated by natural selection (see also Wuketits, 1992). The problem of nonsense constructions will be addressed in the following section.

One of the major obstacles to overcome the (often polemic) controversies between EE and RC is the former's clinging to *hypothetical realism*. Although proponents of EE admit that "*realism involves presumptions going beyond the data*" (Campbell, 1974: 449), they cannot help but claim that it not only exists but that it can also be known: "*[W]hat an organism construct must, one way or another, correspond to some aspects of reality ...*" (Wuketits, 1992: 158).

4. HYPOTHETICAL REALISM FROM A RADICAL CONSTRUCTIVIST PERSPECTIVE

For Vollmer (1987), Russell's 1912 quote (as mention at the beginning of the introduction) was a motivation to compile a list of 13 arguments in support of EE's reality postulate. The first of these arguments he called the *psychological evidence.* It is this evidence that continuously convinces us of the factual existence of a mind-independent reality based on our commonsense reasoning. He refers to Russell's notion of *instinctive belief.* It is caused by experiences of resistance or pain, but also by the fact that other people talk about things out there with the same matter of course as we do—or at least as Vollmer does.

Let us have a closer look at this 'experience of resistance'. One does not need to recur to Riedl's colourful rhino thought experiment, simple questions of the sort "Does this table her in front of me exist?" or "Surely, you still believe that when the door is closed you cannot walk through it don't you?" seem to be powerful enough to refute RC. What, for example, prevents the reader from constructing the fact of reading this article in this very moment and flying over the Grand Canyon an instant later? Obviously there *must be* limits to how the cognitive apparatus constructs reality otherwise RC would render irrelevant. It is of crucial importance to not let an adverb sneak in: Constructing our own world must not be equated with *arbitrarily* constructing our own world. So how to keep the adverb out?

Experiences are made subsequently. As such, they are connected with each other in a historical manner and form a network of hierarchical interdependencies (Riegler, 2001b). The components of such a network are, therefore, mutually dependent; removing one component may change the context of another component. In this sense they impose constraints on each other, very much like the constraints-analogy provided above. By car, you can reach only those points which are connected to the road network, by foot, all the points in between can be accessed as long as they are within walking distance. Each means of transportation restricts the availability of reachable destinations. Free arbitrariness is not possible since different means of transportation have different degrees of flexibility and speed. Similarly, the construction network of the mind is also necessarily non-arbitrary. It follows the canalizations that result from the mutual interdependencies among constructive components. Once a certain path is taken with regard to relating components to each other in a particular manner, the mind uses previous constructions as building blocks for further constructions.

Likewise, the 'reality' of a door and the experience of bumping into it are mental constructs that are mutually dependent. On a meta-level, we can reflect on the components of the compound constructions and do as if we could deal with each component separately, or change the features of isolated entities as if those features would not depend on other elements.

Sometimes, however, there are cases in which we can deliberately change the mutual relationship among constructions to different degrees. Boicho Kokinov (1997: 3) hints at this fact by discussing various steps of accessibility.

> At the lowest end a memory trace could be completely inaccessible (neither consciously, nor unconsciously) at a particular moment, then it could be only unconsciously (implicitly) available (demonstrated by priming effects, but failing to be recognised in an explicit memory task, for example), then it could be consciously available (demonstrated by a standard recall or recognition task), and finally the very fact of existence of the memory trace might be consciously available (demonstrated in a meta-cognitive 'feeling of knowing' experiment).

So certain classes of constructions seem reversible to some degree. Mathematical problems, for example, can get suddenly solved after a mind-relaxing night. Problems regarding the construction of social relationships may already take longer. They sometimes need therapy, e.g., Paul Watzlawick's family therapy (Watzlawick et al., 1974), which tries to reframe a habitual situation to make participants recognize solutions.

Only for constructs with an even longer history and/or bigger number of mutually dependent components we can expect even more insuperable obstacles in somebody's attempt to change them, such as our idea of doors and bumping into them. An indication that parts of our memory are no longer accessible by conscious (and verbal) thought is provided by the results of Gabrielle Simcock and Harlene Hayne (2002) on the puzzle of childhood amnesia, i.e., the phenomenon that we forget about our earliest childhood experiences up to the age of 3. The authors were researching very early verbal memories and found that children can only describe events from early childhood using the limited language they knew at the time. Their ability to remember exceeded their ability to talk about the experimental device that magically shrinks toys—an event spectacular enough to be remembered. One year after their first contact with the machine, the children still displayed the non-verbal procedural knowledge to shrink a toy. However, when trying to recall their memories they were unable to use newly acquired words that were by now part of their everyday vocabulary. Their verbal descriptions of the event were "*frozen in time, reflecting their verbal skill at the time of encoding, rather than at the time of the test*" (Simcock and Hayne, 2002: 229). Therefore, cognitive development seems to resemble a ratchet (see Riegler, 2001a) in that once the individual starts to reason in language it cannot reach back to unconscious procedural memories.[11]

What are the implications for the argument against hypothetical realism? If humans cannot translate their preverbal memories into language, how can basic sensorimotor constructs made in that early period be reasoned about and claimed to be part of a mind-independent reality? As Siegfried Schmidt (quoted in Pörksen, 2004: 134) put it, "*For if I want to know whether this table exists, there already has to be a table in my experiential reality I can deal with. The question of whether this table exists or not is an assertion that neither adds to, nor subtracts from, existence.*" That we can isolate the concept of table from its defining (dynamical-operational) context—to abstract from its embeddedness (Riegler, 2002)—is a remarkable feat of language only, yet it does not make sense on the level of experiences (Riegler, 2005).

The conclusion from this section is straightforward. The argument that we *have to* assume a mind-independent reality in order to account for cognition—based on the claim that purported real things resist our actions and thoughts—is rejected. It rests on the incorrect premises that linguistic-philosophical reasoning (let alone common-sense 'talking about') could reach down to very early (sensorimotor) experiences and assess them appropriately.

[11] This indicates also that constructions are not necessarily linguistic by nature.

5. CONCLUSION

So which perspective is the ‘correct’ one? If following the arguments in the previous section we have to drop the idea of hypothetical realism; speaking of adaptation as the source of cognitive knowledge acquisition does not make sense. The EE literature often quotes Simpson (1963) argument “*The monkey that had no realistic perception of the branch he was jumping for was soon a dead monkey—and did not belong to our ancestors*” (Sjölander, 1997: 596) as an illustration of how important the a priori ontology of a mind-independent reality is. Vollmer (1987: 36) quotes Max Planck according to whom the scientist has to assume the existence (“*als vorhanden annehmen*”) of the appearances and laws which she is searching for. Vollmer, of course, meant to refer to *real* things, to *real* branches, etc. However, from a cognitive point of view the existence of branches is uninteresting. Rather, what ought to be the focus of interest are questions such as “How did the monkey learn to grasp in the right moment?” Consequently, Planck’s statement is to be interpreted in a quite different sense. (1) As cognitive scientists we do not search for real branches—that is left to botanists. Rather we want to learn about cognitive mechanisms. (2) The German expression ‘vor*hand*en sein’ used by Planck relates to the aspect of *manipulation* (Latin ‘manus’ = hand) rather than to *ontological* statements. Knowledge, therefore, is knowledge about change and transformation rather than about static things and relationships (operative rather than figurative knowledge in the sense of Piaget; cf. also O’Regan and Noë, 2001). On which assumptions does such knowledge rest?

It seems that we have to agree with the conclusions of Engels (1999). Traditional problems of philosophy cannot be solved by biology. Out of necessity biology has always to start with the assumption of a reality populated by animals. Since biology always makes existential claims in the first place every attempt to prove the existence of an external mind-independent reality including the existence of other subjects renders necessarily circular. In mathematical-formal systems, where the truth of a proposition is proven by establishing a link of deductive sets between the set of axioms and the proposition in question, you cannot prove the validity of the axioms within the system either. For the validity of propositions within a formal system it is entirely irrelevant whether its axioms are true within a broader encompassing system.

Furthermore, does not restricting itself to experience rather than letting a mind-independent reality be the (easy) arbiter of hypotheses and theories severely limit the range of applications of RC? I maintain that, quite on the contrary, RC has a *broader* scope than EE. By putting the emphasis on *observing* systems rather than on *observed* systems (Foerster, 1984), RC not only includes observed systems but also attempts to account for observing.

Consequently, it demands from science to develop a *theory of the observer*: "*Since it is only living organisms which would qualify as being observers, it appears that this task falls to the biologist. But he himself is a living being, which means that in his theory he has not only to account for himself, but also for his writing this theory*" (Foerster, 1984: 258). While EE is at the mercy of its own a priori settings regarding the threat of self-contradiction and circularity (as it tries to explain its own axioms, i.e., the biological a priori of cognition), the biological roots of RC are but a basin of its argumentative attractor. For example, the principle of undifferentiated encoding of nervous signals resulting in cognitive closure does not rest on the assumption of a (hypothetical) realism: Whether *or not* we assume the reality of undifferentiated encoding in the nervous system we cannot escape the fact that it is organizationally closed. Hence it is impossible to speak about reality. It is a Wittgenstein ladder leading to the insight that the purported mind-independence of reality cannot be considered an axiom. As Glasersfeld (1995) pointed out we cannot verify our belief in a mind-independent reality if all the means we have to validate it are the senses through which we gathered the sensor data on which the belief rests. This situation compares to being prosecutor and judge at the same time: It renders independent validation impossible. Therefore, we not only have to put up with experiences as the sole point of reference; we also have to re-consider the nature of 'reality'as useful everyday construction at best. In other words, RC does not ask the question of EE: "What are the Kantian a priori?" Instead, constructivists stress the fact that we can never know anything about the thing in itself, *das Ding an sich* (Sjölander, 1993; Riegler, 2001b).

The arguments brought forth in this paper suggest two solutions for the RC versus EE dilemma. First, from a modelling perspective a collaboration between EE and RC appears possible. *Ontogenetic* aspects of cognition can be modelled by applying ideas of constructivism, which underlines the organizational closure of cognitive systems. This means that the cognitive apparatus deals exclusively with its own states. Only through a transduction shell, which works *independently* of the cognitive apparatus, sensor inputs to internal are mapped onto states, and which are mapped back to outputs. *Phylogenetic* aspects are modelled along evolutionary theories and follow insights from EE. This means that a population of organizationally closed agents starts with phylogenetically inherited cognitive structures representing innate *anschauungsformen* (Riegler, 1994). This implements Lorenz's *lehrmeister*.

On a philosophical level, however, the mutual rejection in spite of common grounds could also be interpreted as a paradigmatic example of Josef Mitterer's (2001) treatise on dualistic ways of (scientific and philosophical) knowledge acquisition. Dualistic approaches, being the prevailing scientific orientation, are based on the distinction between description and object, and their argumentation is directed towards the object of thought. Mitterer's thesis says: The dualistic method of searching for truth is but an argumentative technique that can turn any arbitrary opinion either true or false. Epistemological paradigms become visible in hindsight: Another university, other teachers and an evolutionary epistemologist would have become a radical constructivist, and the other way around. For example, Lorenz's statement (quoted after Sjölander, 1997: 595), "*we only perceive the world indirectly, i.e., what I see, hear, touch or smell is a world created—constructed—within my brain, it is by no means a picture of the world as it actually is*" could have been written by a radical constructivist as well.

In conclusion, the main difference between EE and RC is the respective setting. For EE living systems are defined over their output. The basic assumption of EE is a world populated with entities, i.e., a world that consists of matter. The RC perspective, however, suggests that for living organisms the output is just a means to control their input. They act in order to keep input states in equilibrium. Therefore, for a living being the world consist of what matters. This does not mean that according to RC "the world is exclusively in the mind/head" because this reproach assumes a world that consists of matter, including heads. Despite forgoing this assumption in RC, there is no arbitrariness of world construction. It is prevented by mutual dependencies among construction elements rather than through an alleged external reality. Furthermore, RC interprets the basic assumption of EE as part of the organism's strategy to keep its input stable. In order to regulate the input through its outputs the organism introduces a causal chain carried by hypothetical entities in its environment through which its input is ultimately affected. EE remains on the level of the description of this causal chain and considers it *the* reality whereas RC regards it *a* reality. Therefore, the EE perspective is a subset of RC.

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The biological boundary conditions for our classical physical world view

Olaf Diettrich

Centre Leo Apostel, Vrije Universiteit Brussel, Brussels, Belgium
olaf.diettrich@skynet.be

Abstract

It is shown that the laws of nature providing us with cognitive survival competence are not objective properties of the world, rather they depend on the previously acquired phenotype in the same sense as the acting competence of organisms depends on the previously acquired organic phenotype. For example: the law of energy-conservation can be derived from the homogeneity of time. But homogeneity in time is defined by how our internal clock (which is part of our phenotype) is constructed. Cognitive evolution is subject to the boundary condition that will result in a world view (i.e. physics) that has to be invariant under all we do within this world-view. As locomotion is the oldest and most important capability of our ancestors our world view must be invariant first of all under locomotion, i.e. it has to be Galilei-invariant.

Emmy Noether has shown that this is sufficient to derive the 10 conservation laws of classical mechanics. The other so-called laws of nature are defined as invariants of physical measurements. Therefore, cognitive evolution itself has brought about what we call the laws of nature and, therefore, cannot be subject to these laws as advocated by Campbell.

1. INTRODUCTION

It is an old understanding in evolutionary sciences that our cognitive phenotype evolves in similar ways as the organic phenotype does. Both are subject to boundary conditions based on the structure of an independent outside world. The central terms are adaptation to and selection by the environment. How the process of adaptation acts in the case of the organic phenotype is described by the theory of Darwin: the central topic is blind variation and selection. The cognitive analogue is described by Campbell's *natural selection epistemology* (1974), saying that the development of human knowledge is driven by a process analogous to biological natural selection in the sense that the possible fit between our theories on the world and the world itself can be seen as a process of trial and error.

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But trial and error is a little bit too simple an explanation for complex matters such as the organic or the cognitive phenotype. First of all, the environment is not that dominant as people usually think. The selection pressure which a certain habitat will exert on an organism living there does not only depend on the structure of the habitat. It depends on the structure of the organism itself as well. Horses and snakes, for example, though they may have developed in exactly the same physical environment, have entirely different organs of locomotion which have no structural element in common (Diettrich, 1989: 22). And, accordingly, entirely different will be the selective pressure they have to meet. Horses (among others) have to improve the elasticity of their limbs and the strength of their muscles. Snakes have to improve the surface friction of their skin.

That evolution is not exclusively a matter of assimilation according to the selection pressure was already pointed out by Waddington (1959: 1636):

> Animals are usually surrounded by a much wider range of environmental conditions than they are willing to inhabit. They live in a highly heterogeneous 'ambience', from which they themselves select the particular habitat in which their life will be passed. Thus the animal by its behaviour contributes in a most important way to determining the nature and intensity of selective pressures which will be exerted on it. Natural selection is very far from being an external force, as the conventional view might lead us to believe.

So we can say: further evolution depends on previous evolution. Riedl (1975) speaks in terms of the 'genetic burden' which a species has to consider when further to evolve. We can generalise this; problems (such as locomotion on steppe-like landscapes) do not determine the methods of their solution—or, what is the same: many different organic phenotypes can live in the same habitat. They all have brought about different solutions, so to speak. The opposite inference cannot be made either. We cannot derive from a 'solution' the kind of problem for which it was made, nor can we see for what purpose a technique an organ is to be used (before we have seen it)—particularly not if there is more than one possibility. A bird's bill for example could be suitable for picking corn, cracking nuts, fighting or climbing. In the organic area there seems to be no relation between problem and solution. The consequence is that organic evolution has no specific focus towards which all species will converge, the '*pride of creation*' so to say.

Here we come to a massive conflict with cognitive evolution. According to common understanding cognitive evolution (insofar as it aims at mastering the physical environment) is confronted only with the structure of nature represented by the laws of nature. Generally speaking: the better the cognitive phenotype is, the better it will recognise and interpret the laws of nature.

Transferring what we said on organic evolution to cognitive evolution would mean that there is no link between the theories we construct to master the world and the structure of the world to be mastered. i.e., we had to admit that epistemic evolution does not necessarily progresses towards a goal, towards a definitive set of natural laws (towards '*truth*' or towards a '*theory of everything*' (Barrow, 1990), the '*pride of science*' so to speak). Indeed, this would be hard to accept. We may admit that theories are not pictures of the world in the sense of downright realism, but we firmly believe that theories on nature have to meet requirements which are defined exclusively by the outside world so that living in an entirely different world (à la Leibniz) would require entirely different theories. Indeed, most scientists would flatly reject the idea that there is no link between the world and our theories we use to master the world (i.e. between problem and a solution). This—so they fear—would lead directly into the 'everything goes' trap.

This classical view is based on the assumption that our perceptions can contribute to mastering nature only if they are correlated to nature either structurally (depicting realism) or functionally (constructivism). Therefore, in either case, it holds that our perceptions and the theories we derive from them are statements on the world in the sense we just mentioned.

This is equivalent with the view that there is a clear distinction between perception and action. By means of perception, we generate knowledge and theories on a predefined outside world, and by means of action, we operate on just this world and because of this change it. This view, however, is difficult to hold in physics (particularly in quantum mechanics) where measuring (i.e. perceiving) is itself a kind of acting. Measuring is carried out by measuring devices acting as operators on the objects in question. Measuring results, i.e. the structures we 'see', are defined as invariants of the measurement operators. This means that there is no essential difference between acting in the literal sense and acting by means of measurement operators. It was a far reaching decision of physicists to accept, as far as possible, objects, features or other theoretical terms only if they can be defined by means of a measurement process. This was triggered by painful experimental evidence showing that the usual proto-physical definitions of theoretical terms by means of common sense may not be suitable to describe subatomic or relativistic systems. Theoretical terms have to be defined more precisely, and this can be achieved by means of measurement devices. This is called the operational definition of theoretical terms.

Objects are defined by their properties and properties are defined as invariants of measuring operators. So, objects too are defined by means of operators. As we can neither measure a property nor act upon the object in question without the preceding application of defining operations (i.e. defining the properties which characterise the object in question), we can conclude that all we see and do is a matter of interaction between three different kinds of operators: defining, measuring and acting operators. In other words, what a perception is going to tell us, or what an acting will bring about depends on how the object perceived is defined.

2. THE RELATIONSHIP BETWEEN ACTION, PERCEPTION AND DEFINITION

The concepts of action, perception and definition need some elaboration before we fully can understand them. Acting (be it acting by ourselves or acting by other subjects or systems) means everything which modifies perceptions. Acting can be acting in the literal sense such as modifying a physical object and by this changing what we see of the object as well as acting by means of our locomotion limbs and by this changing the perceptions concerned due to perspective phenomena. The only direct access we have to objects are perceptions. Then we can use the notion of operators acting on perceptions and transforming them into other perceptions. For saying so it is not necessary to declare that perceptions are perceptions *of* something or that perceptions would tell us something about matters which *exist* independent from our perceiving them. The only important matter is the interaction between action and perception. To explain this in more detail we will apply a formalism here which is quite similar to what is used in quantum mechanics:

φ, χ be normalised vectors in Hilbertspace and represent perceptions.
O, P be Hermitian operators in Hilbert space and represent operators acting on perceptions.
λ_i $(i = 1, 2, \ldots)$ be the (real) eigenvalues of Hermitian operators.

Let us consider all the perceptions φ_i $(i = 0, 1, 2, \ldots)$ which are invariant under the action of an operator O:

$$O\varphi_i = \lambda_i \varphi_i \tag{1}$$

We will call a subset of eigenvectors φ_i of O the O-representation if any perception ψ can be described as a linear combination of the φ_i

$$\psi = \sum \alpha_j \varphi_j \tag{2}$$

Our saying is that ψ is defined by O.

Formula (1) can also be read in another way: if the φ_j are defined by another operator, say N, which commutes with O (i.e. ON = NO, or, what is synonym, which are commensurable with O), then (1) represents a measurement process and the λ_i are the possible measurement results. This relationship is symmetric. Both O and N can be defining or measuring 'operators', respectively. In the

O-representation we can measure by means of N, and in the N-representation we can measure by means of O.

If N and O do not commute (NO $\neq$ ON), then N will transform a perception (which is eigenvector φ_i of O) either into another eigenvector φ_j of O or into a perception χ which is no longer an eigenvector of O at all. In this case we will call N an acting operator rather than a measuring operator. The same applies for the opposite direction. So, we come to the

Operator's lemma: whether an operator can be used for measurement or for action depends on whether it will commute with the operator defining the object in question or not.

To make this point clearer let as pose the question as to whether our walking limbs are acting or measuring operators.

In a 3D world furnished with objects which are defined as invariants of spatial transformation, locomotion is a measurement process (when walking around an object the various views perceived will inform us on the object's shape, i.e., we will 'measure' the shape). For someone who sees the world in two dimensions (i.e. for someone who does not know perspective phenomena), however, locomotion is a (remote) acting operator because it modifies the shapes concerned. What does that mean?

To see the world in three dimensions allows us to distinguish between the (visible) reduction of size due to physical compression and that due to enlarged distance. But we cannot say that our space of visual perception is 3D because the world itself is 3D in character, and that 2D-apes which do not see the world in three dimensions were unable to jump from tree to tree, and, therefore, could not belong to our ancestors as Konrad Lorenz (1941) argued. It is easy to show that appropriate and successful survival strategies could well be based on 2D or 4D perception spaces, independent from how many degrees of freedom are actually available.

With a 2D perception we would not know perspective phenomena. Things are small or things are big, but they don not seem to be small because they are more distant and they would not seem to be big because they are nearer. Distance to the observer belongs to the third dimension which is excluded here. But objects, nevertheless, would shrink in size if we use our legs to go backwards and they would enlarge their size if we go forward. So, with a 2D perception we would come to a world view according to which not only our hands and mechanical tools can modify objects but also our legs. So walking limbs were acting operators. This must not lead to the conflict mentioned by Lorenz. With such a perception, an ape may well be able to jump from branch to branch. The only thing he has to learn is that he has to grasp the branch envisaged just when its size and position achieved certain typical values. If the perceived size of a branch will have doubled after three steps, the ape must know that he will arrive at it after another three steps and then has to grasp. If he has learnt to do so he may well survive in forests and an external observer would not find any difference between the moving strategies of such an ape and those based on a 3D perception. So, whether walking is a measuring or an acting operator depends on whether the objects in question are defined as invariants of 3D or 2D transformations. It is evident that physical theories based on an inborn 2D world view where objects could be 'deformed' not only by means of our hands but also by means of remote forces brought about by our walking or jumping legs would have no similarities with the theories we are used to use. Such a world view—and this is the point—must not be less successful than ours is. Also organic organisms can be seen as an answer to the question of how to survive in a given habitat. Many different organisms can live together, which shows that they all are well prepared to survive.

We can explain the relation between two and three dimensions with another example: Let us imagine locally fixed plants that have eyes and can see and which may have acquired a 2D perception. They would tell you that they have smaller and bigger companions. For us, this would be due to different distances, but not for these plants. As soon, however, as they learn to communicate and would tell each other what they see, they would find out that what is small to one observer, might well be big to another one. After some perplexity they may construct a theory of relativity of size, saying that size is nothing absolute but depends on the relative position of observers—difficult to understand for someone who is used to live in a 2D perceptional space. Exactly the same happened to physicists when empirical evidence forced them to construct the theory of special relativity saying that time intervals are nothing absolute but depend on the relative motion of the observer—difficult to understand for someone who is used to live in a Newtonian world. (By the way, this analogy can be extended: the (relativistic) limitation of all speeds in the 3D case ($v < c$) corresponds to the limitation of all lengths in the 2D case, as these can be defined only by means of the aperture $\alpha < 180$).

That certain modifications of visual perceptions can be interpreted as a perspective (or geometrical) phenomenon or as a phenomenon of explicit physical action, is well known from another case in physics: the orbits of planets could be considered as the effect of explicit gravitational forces (the physical solution) as well as the curved geodetic lines within a 4D space (the geometrical solution as proposed by the theory of general relativity).

As all this is just a different interpretation of the same observations we can neither come to a decision on empirical grounds nor was adaptation or selection relevant when cognitive evolution of primates had to decide whether to see the visual world in two or three dimensions. In other words, perceptional spaces and systems of categories are purely descriptional systems which may tell us something on how we see the world but nothing about the world itself. So they cannot be the outcome of adaptation to the world. From this it follows that our epistemology cannot be a natural (i.e. external) selection epistemology as advocated by Campbell.

But, could it not be possible that our epistemology is an internal selection epistemology, i.e. that certain elements of our epistemology are easier to realise by our cognitive phenotype than others and, therefore, are selected in the course of our cognitive evolution? The spatial shape of objects we describe in 3D perception, for example, is something nobody has ever seen. All we see are 2D projections on the retina of our eyes. The spatial character of perceived objects is a cognitive artefact which requires a lot of internal arithmetical efforts to be realised. In 2D perception, however, things are as they appear. So, from the mathematical point of view, two dimensions are privileged with respect to three dimensions. On the other hand, 2D perception requires an explicit physical theory on the correlation between what our legs are doing and what we see. In 3D perception this is solved implicitly. The correlation concerned is a matter of geometrical perspective comprised in the notion of a 3D space. Therefore, we can propose the following view: the fact that our cognitive evolution ended in three dimensions rather than in two can hardly be due to mathematical economy (which, of course would favour two dimensions) but rather is due to what we will call the principle of implicit description: cognitive evolution tends to take away approved experiences from explicit description and puts it into implicit description, more specifically into the special character of the world view (methatheory) concerned. Then, the regularities we found are no longer a particularity of the 'world' (which may well be different in a different world) but the intrinsic consequence of the world view we use.

3. WORLD VIEWS

A world view is defined by the decision of what we call acting operators and what we call defining or measuring operators. As we have seen, 2D and 3D perceptions constitute different world views as locomotion is *acting* within 2D perception, and *measuring* within 3D perception. Within a world view the relationship between defining, measuring and acting is described by theories. Outside a given world view it is not defined what a theory will mean. A theory shall be called complete if it can describe everything that can happen within a given world view. An equivalent saying would be: a world view is characterised by any of its complete theories. A complete theory is another saying for what otherwise is called the *theory of everything*. There is an ongoing debate as to whether there is a theory of everything—the final focus of nature sciences so to speak. Yes, of course, there is one, as we have seen here, but only within the context of a given world view. Outside a world view a theory of everything is not defined. Particularly a context free theory of everything, i.e. outside any world view (and by this objective), is not defined. But just that is what people usually have in mind when discussing the theory of everything. On the grounds of what we have shown here an objective theory of everything does not only not exist—it is not defined and, therefore, without meaning.

It is as we would try to describe geometrical structures without the notion of metric spaces in order to escape the particularities of the various spatial reference frames. In each of these frames the structures have different characteristics, but it is impossible to define geometrical characteristics without any frame, i.e. without referring to the notion of space.

3.1. Cognitive Operators

Within what I called *constructivist evolutionary epistemology* (CEE) (Diettrich, 1994a) let us introduce here the so called *cognitive operators*. We will assume that they are physiologically implemented somewhere in our brain and that they transform certain states of our sensory apparatus into what we call perceptions (Diettrich, 2001). Their invariants are the regularities we perceive. So, these phylogenetically acquired human specific cognitive operators are the defining operators for all the regularities we see and which are specifically human specific as well. Insofar as we condense observed regularities into laws of nature, these laws are also because of this human specific rather than objective. (For example: the law of conservation of energy can be derived from the homogeneity of time. But what homogeneous means depends on our internal clock realised by physiological processes. The law of energy conservation, therefore, is a human specific artefact). Our inborn cognitive operators define our inborn classical world view and by this the laws of classical physics.

Typical of most empirical sciences is the use of instruments and measurement devices (such as microscopes or X-ray devices) by means of which we extend the range of natural perception in ways similar to those we use to extend our inborn physical capabilities by means of tools and engines.

Here we have to distinguish between two important cases (Diettrich, 1994a). We will speak of *quantitative extensions* if the inborn perception (or cognitive) operators and the measurement operators commute. This means that the results of the measurement operations can be presented in terms of invariants of the inborn cognitive operators, i.e., in terms of our classical world view.

We will speak of *qualitative extensions* if at least one of the measurement operators concerned is incommensurable with one of the inborn cognitive operators. Then the results of these measurements can no longer be presented in a classical manner and would require new, non-classical theories, more specifically theories from non-classical world views. This happened first with measurements in subatomic areas which lead to the establishment of quantum mechanics. As the set of possible measurement devices is, in principle, unlimited, it can never be excluded that qualitative extensions of previously established operators will require modifications of the previously established world view and of the theories associated with it. So there will never be a definitive world view and there will never be a definitive 'theory of everything' (Barrow, 1990; Diettrich, 1994b). No objective laws of nature will ever be formulated. Those laws we have, have been 'constructed' in a human-specific way in the course of human evolution. They will never converge towards a definitive set of laws.

Here is an interesting analogy to mathematics: physical laws from which we can derive everything that can happen in nature (our classical saying) correspond to the axioms in mathematics from which we can derive everything what can 'happen' in mathematics, provided they are complete and definitive (our classical saying according to Hilbert).

However, just as experimental operators, though constructed entirely according to the rules of classical physics, may lead to results which cannot be described in classical terms, we know from Kurt Gödel (see the summary of Nagel and Newman, 1958) that there are mathematical calculi which, though based entirely on well tested axioms, can lead to statements which cannot be proven within the context of these axioms, and, therefore, have to be replaced by a new set of axioms—and this can happen again and again. So we have qualitative extensions in mathematics as well as in physics. The reason for that parallel may be found in the fact that mathematics can be considered as part of our cognitive phenotype and, therefore, that axioms can be seen as the mathematical parallel to the natural laws in physics.

With this, the incompleteness of natural laws in physics and the incompleteness of mathematical axioms are homologous cognitive phenomena. Neither is there a definitive set of physical theories (no theory of everything) explaining and describing all (also future) physical problems nor is there a definitive set of mathematical axioms determining the truth value of all possible mathematical statements (Gödel's incompleteness theorem).

We can conclude that the laws of nature are not objective but rather are human-specific artefacts. We may ask what consequence this may have for the central metaphysical notions such as reality time (particularly the metric and the arrow of time and causality).

3.2. Reality

We have seen that our inborn cognitive operators are responsible for what kind of regularities we will perceive—and hence are responsible for the laws of nature we derive from the perceived regularities. This leads to a different notion of reality. Let us distinguish the following notions:

(1) *Actuality* (Wirklichkeit) means the physical structure of our environment which we should not ignore. Indeed, ignoring trees when running through a forest can be painful. Insofar it is close to reality. But we can modify actuality in many cases by means of physical actions.
(2) *Reality* is that part of actuality which we cannot modify by what ever means. According to classical thinking this only holds in the strict sense for the laws of nature. Questioning reality in the way we are doing here, therefore, means nothing but questioning the objective character of the laws of nature. This is strange enough, but it does not provoke any solipsistic fears which many people share when confronted with what they call anti-realism.

For our day-to-day life this has no consequences. Up to the day where a new qualitative extension of our scientific doing will require to modify our world view, the laws of nature we 'found' are stable and definitive and, therefore, can well represent what we call reality. But we have to keep in mind that this reality has no ontological qualities. It just is a synonym for the totality of the physical laws we found within our phylogenetically acquired special world view.

3.3. The Arrow of Time

After we have seen that the notion of reality is difficult to hold we have to ask what to do with the other metaphysical notions such as time and causality if we can no longer consider them as belonging to a 'real world'. Particularly crucial is the so-called arrow of time, i.e. the direction into which time 'flows'.

Within the context of our day-to-day experiences we have a very clear understanding of what past and future is. Past is what embodies all the events we have experienced. Past is the source of all knowledge we have acquired. Future is the subject of our expectations. Future embodies the events which may happen and which we have to await in order to see if they really will happen. How can we express this by means of physical theories? Or, more precisely and according to the operationalisation concept: Are there devices or processes which can operationalise the terms past and future, i.e. time's arrow?

Many efforts have been made in this direction (Zeh, 1984). The result is short and disappointing. In all cases where it is said that the arrow of time has been operationalised it can be shown that the direction of time was already comprised implicitly in the preconditions of the experiments concerned. A typical example is the following: Shaking a box with black and white balls put in order according to their colour will always lead to disorder and never again to order. In physical terms, entropy (which is a measure for disorder) will increase in time and never decrease. Entropy, therefore, seems to operationalise the arrow of time. But in this case the result will depend on what we do first, separating the balls or shaking them. Shaking before separating will lead to order. Shaking after separating will lead to disorder. So we already have to know what the terms before and after mean before we can do the experiment which is to tell us what before and after will mean. Another example: a hot physical body left in a cooler environment will always cool down. But this applies only if the collision processes between the atoms involved are endothermal, i.e. if the kinetic energy of the collision partners are higher before the collision than they are afterwards. If we, however, have exothermal processes which are characterised by the fact that the kinetic energy of the particles involved is higher after the collision, then the body will heat up rather than cool down. Here again we have to know what before and after means in order to define the collision process which will define the result of the experiment which is to define the arrow of time.

These are particular examples. Prigogine (1979: 220) has shown more generally that irreversible processes in thermodynamics cannot help us to operationalise the arrow of time. The existence of the so called Ljapunow-function—which is closely related to macroscopic entropy—is also a prerequisite for the distinction between past and future in microscopic systems. Unfortunately, the Ljapunow-function is ambiguous with respect to the arrow of time. It can be constructed in a way such that equilibrium will be achieved in the future as described in classical thermodynamics but it can also be constructed so that the equilibrium will be 'achieved' in the past.

From all this one can propose the hypothesis that in principle the arrow of time cannot be operationalised objectively, i.e. it cannot be derived from what we call nature. What past and future means then, can be described only by means of a sort of mental operationalisation. The following definition, for example, may be suitable: From two perceived events A and B, A is said to be before B if we can remember A when B happens but not B when A happens. Of course, past is what we can remember but we cannot remember future. This 'mentalisation' of past, present and future, I think, is very close to what Einstein (published 1972) may have had in mind when he wrote to his friend Bosso 'that these categories are sheer illusions'.

3.4. Causality

In order to constitute causality we must be able to identify patterns of events. If a number of events, say A, B, C and D follow each other always at typical intervals independent of when the first one occurs (i.e., if the pattern is an invariant of translation in time), then we say that there must be a causal relationship between the events concerned. Otherwise the perceived regularity could not be explained. Causal relations then are defined as invariant patterns of time (Reichenbach, 1924). This, however, requires more than just having a topology of events as provided by our memory. We must also be able to distinguish between shorter and longer intervals of time, i.e. we need a time metric defined by a mental metric-generator implemented physiologically somewhere in our brain. For example, that we say lightning is the cause of thunder but not the contrary is based on the fact that the time between lightning and the next thunder is usually much shorter and varies less than the time between thunder and the lightning. But the length of time intervals can be defined only by means of a time metric. If our time metric generator were of the kind that it would be accelerated after a flash of light and retarded after an acoustic event we might as well come to the conclusion that thunder is the cause of lightning rather than the other way around. *The mental time metric-generator is, therefore, responsible for the causal order established and for the prognostic capability derived from it.*

4. THE BOUNDARY CONDITIONS

Up to now we explained that there is a large potential of different and possibly successful world views (one of them is our own phylogenetically acquired and inborn cognitive phenotype) and that their success is not a matter of adaptation to something independent or external. What we did not say up to now is what structure or what properties a cognitive phenotype must have in order to be successful. This is indeed necessary because a completely arbitrary or accidental cognitive phenotype can hardly be expected to be helpful. To begin with, there are two requirements any cognitive phenotype has to meet.

(1) The tools we use to describe (i.e. to measure) the results of our doing must be independent from what we do. Otherwise we could not distinguish between what part of a modified perception is due to our doing and what is due to a modified description. More specifically our describing tools must be invariants of as many as possible of our acting operators. Constructing descriptional tools which are invariant under these operators is what cognitive evolution should aim at. Then the operators concerned become measuring or cognitive operators, i.e., they identify properties of the objects concerned. Unfortunately we cannot construct a world view without acting operators, where the result of everything we may effect is (such as perspective phenomena) comprised implicitly in the world view. But cognitive evolution can aim at a world view where at least the most important and most frequently used acting operator will bring about appropriate and invariant defining and

measurement operators. Such an acting operator is locomotion (indeed, locomotion is one of the most important and earliest operators organic evolution has created). Here, indeed, cognitive evolution found an appropriate tool: 3D-description. 3D-defined geometrical objects are invariant under locomotion (or, as a physicist would say, under Galilei's transformations). The properties of these objects, i.e., their shape is measured by means of perspective phenomena brought about by locomotion. In other words: all the geometrical objects we derive from what we see as perspective phenomena are invariants of locomotion.

But this is not the aim of cognitive evolution. If we walk long enough it may happen, that the city we just perceived is transformed into a forest. The respective pictures have nothing in common, nothing is invariant. So it seems that what we see is no longer invariant under walking conditions. In order to save the concept of locomotion as a measuring operator cognitive evolution made a big invention: space. A space is a matter of different places, each one having different properties and different appearances and all existing in parallel at the same time. So, walking from one place to another and by this having different perceptions does not require or does not mean that anything has to be changed or transformed because all the different things we would perceive did already exist before. So, defining visually perceived geometrical objects as invariants of locomotion requires the notion of space brought about by motion. Something similar has been discovered by Piaget (1970, 58). Because of research on children he found that it is not the category of space that allows us to define motion as mapping a line in space to the scale of time. It is rather motion that generates the category of spatial structure. The most primitive intuition, as Piaget called it, is not space but motion. Here we can clearly see that it is the physical structure of our organism (including walking limbs) that brought about the cognitive category of space rather than that the ability to move was brought about by evolution in order to master a previously perceived space. Thus the physical structure is the boundary condition for the subsequent cognitive evolution.

(2) The central demand on descriptive systems is their suitability for extrapolation, particularly for extrapolation in time, i.e., for prediction. Indeed a description which does not allow the easy prediction of what will happen or what our doing will bring about, cannot contribute to survival strategies. Easy predictions are possible if the variables in question would change linearly in time. If something moves permanently with constant speed it is easy to say what it will do in the near future. Unfortunately, such cases are rare. In most cases the solution of the equation of motion is complex and difficult to handle. Here the theory of Hamilton–Jacobi is useful and allows in many cases to transform the variables in question in such a way that they will develop linearly in time. These new variables are called cyclic.

A reasonable aim of cognitive evolution, therefore, is to use variables which are cyclic straight from the beginning. First of all: cyclic variables can be derived from conservation laws. We already mentioned the law of conservation of momentum. In force-free cases the speed of a mass-point is constant, i.e. the mass moves linearly in time and, therefore, is cyclic. So, the problem is reduced to finding conservation laws. This problem was solved by Emmy Noether, one of the most famous mathematicians of the 20th century. The so called Noether's theorem links the invariant properties of a system with its conservation quantities: *To every invariance there corresponds a conservation law and vice versa.* The formal statement of the theorem derives an expression for the physical quantity that is conserved (and hence also defines it), from the condition of invariance alone. For example:

- the *invariance* of physical systems with respect to *translation* brings about the law of conservation of *linear momentum* (and by this the cyclic character of force-free motion);
- the *invariance* with respect to *rotation* brings about the law of conservation of *angular momentum (and by this the cyclic character of force-free rotation)*;
- the *invariance* with respect to *time* brings about the well known law of conservation of *energy* (and by this the linear metric of time).

Taken together there are 10 laws of conservation which arise from the invariance of our descriptive system with respect to the Galilei transformation. But invariance under Galilei-transformation, we remember, was synonym for the demand, that our descriptive system must be independent from the most elementary action, that is locomotion. For a physicist it is really astonishing that the 10 conservation laws which govern anything in classical mechanics are not independent laws of nature but are the outcome of the phylogenetic decision to take the Galilei transformation as a measuring operator.

To derive the properties of a system from its symmetries (i.e. the invariants) is a method very successfully applied in higher elementary particle physics. Here the various particles are defined as invariants of higher forces. Most of them were predicted by sheer invariant considerations—long before they have been found experimentally.

5. LANGUAGE AND MATHEMATICS AS THEORIES OF OUR WORLD VIEW

What is crucial here is that our theories of what we call the world are not the result of adaptation to the boundary conditions of this world. Theories are rather the outcome of phylogenetic decisions on our cognitive phenotype guided by rather elementary requirements such as predictability or to get a feasible management of our organic capabilities.

Let us demonstrate this with two other kind of theories which we usually do not call theories: language (Diettrich, 1997) and mathematics.

Indeed, in the ordinary notion of language as rooted in realism, there is no reason to see language as a theory. It rather proceeds on the assumption that language is a universal and objective tool for the description of independently existing objects and processes, being able to convey any usual experience. Certainly, natural sciences sometimes require to extend ordinary language into mathematical areas, but this is not regarded as conflicting for the neutral character of language. Common sense understands that neither language nor mathematics would have any effect or influence on what it may describe. Mathematical methods, as we know, allow us to extrapolate physical data and by this to predict new data, but this is not seen as an achievement of mathematics. We rather believe that it is the special physical structure of the world which would permit its inductive analysis. Experimental physical facilities and the results they produce represent another kind of language. They differ from ordinary written texts mainly by the fact that their decoding would require physical competence whereas the analysis of written communications needs language competence. On the other hand we know from physics that there are no absolutely interaction-free relations between object and measurement apparatus, i.e. nature and the methods of its decoding cannot be completely separated from each other. So, strictly speaking, it should depend on the methods we apply what kind of statements we have to make about nature. Scientists try to avoid this difficulty by using only statements which they believe to be general enough not to depend anymore on the experimental methods, i.e. on the 'language' employed—or, in physical parlance: statements on nature should be invariant under the empirical methods applied. So, the knowledge of what we call the structure of nature is obtained through abstraction from the experimental techniques concerned—like the meaning of a message which could be defined as what is invariant under a change of language. According to naive understanding, language represents a generally unspecific capability independent from whether it is articulated in verbal or mathematical terms or in terms of experimental facilities. Nothing in the specificity of our life experiences is based upon the specificity of our descriptive tools. Language, within the limits of its competence, is seen to be objective and omnipotent. This is what expresses the naivety of the ordinary notion of language: to assume that content can be separated from representation. A similar view on the universality of language (though not necessarily to what is existing, but with respect to what may be intended) is expressed by Searle (1971) in his 'Principle of Expressibility' according to which everything that can be thought, can be said.

Here we have to differentiate the notion of theory. As to compare phylogenetically acquired cognitive devices with organic instruments such as homoeostatic mechanisms, antlers or limbs, it was the idea already of Lorenz (1971: 231–262) and Popper (1973: 164) to see theories and organic devices under the common aspect of survival tools and to consider either of them as theories in the broader sense. This suggests the distinction between two kinds of theories:

(1) *Theories in the structural sense (structural theories)*: They are considered to be a picture, an image or a mapping of a given or created object. This understanding of a theory is mainly found in the natural sciences and in mathematics. Accordingly, theories are considered to be true insofar as they are isomorphic with the structures to be described. Structural theories require that the objects concerned have an independent if not ontological character.
(2) *Theories in the functional sense (functional theories)*: Lorenz (1971: 231–262) and Popper (1973: 164) have suggested enlarging the notion of theory towards all kinds of problems solving instruments. This would comprise physical theories in the proper sense insofar as they help us to master technical problems and to control physical nature; the inborn categories of space and time we use to interpret perceptions and to coordinate mechanical activities; limbs as instruments for locomotion; biological species as an instrument to meet the particular requirements of a special biotope; social communication and social bodies arising from it as a tool to meet the requirements of a wider social environment. All these various kinds of theories we shall call theories in the broader sense, as opposed to rationally generated theories in the usual sense such as physical theories. The latter can be both structural theories (if they claim to depict structures of the world) and functional theories (if they can provide us with correct predictions).

First of all, language is a functional theory in the sense explained here (Diettrich, 1997). No doubt that language is a proved and important tool for solving technical and social problems. But language is also a structural theory insofar as it articulates in a rather precise manner essential parts of our world picture. We can read from language that we experience ourselves as individual subjects who see the world as an object: most statements of our language deal with subjects which behave grammatically as if they were individuals themselves (in some languages where necessary, even an ‘it’ will be constructed as an impersonal substitute person). The distinction between adjective and noun shows that we subdivide the world into single objects to which we attribute features which in principle can change—except a special one which is by definition unchangeable and which we call identity. (We have seen above that these and other conservation values have no ontological quality and can be seen only as invariants of certain operators. The category of identity has developed phylogenetically as invariant of motion (Piaget, 1967) or, as Uexküll said (1921): "*An object is what moves together*".) Prepositions and the forms of predicates disclose our belief that we can attribute to any subject a place and to any event a time. (Now we know that this is not always possible outside the world of classical physics). Conjunctions refer to the causal and logical structures we ascribe to the world, and personal pronouns reflect social categories, (i.e. the view that there are besides ourselves still other beings having principally the same quality of individuality). Many languages transfer nearly all relations into spatial pictures, even causal and modal relations and relations in time. This can be seen best with prepositions which to a high degree derive from local adverbs. We say *in* an hour, *out* of the question, *beneath* contempt, *beyond* all measure, *through* fear, *under* these circumstances, *on the grounds* of, etc. A plausible explanation could be that our 3D world is very much more widely furnished than the merely one-dimensional categories of time or causality, and, therefore, is a more fertile source for metaphorical loans. Taken together we can say that there is a subtle correspondence between language and the more general experiences man has made in their wider history. Basic experiences which for phylogenetic reasons are common to all man and which, therefore, do not need to be told to anyone, are fixed elements in the grammar of human languages (the inborn view, for example, that our daily life acts within a 4D space–time frame is an intrinsic part of our grammar so that in ordinary language other descriptions are even impossible). They form the coordinates by means of which the variable and individual parts of our experiences can be notionally localised, i.e. described. Natural languages represent a kind of basic or Ur-theory of the world. In this respect they correspond well to what we would call a theory in the ordinary sense. Those parts of physical knowledge, for example, which we consider to be generally valid we put into the mathematical structure of the theory and in the values of the parameter concerned (i.e. into the 'grammar'). The variables of the theory, however, refer to the various possible statements.

Conversely, a language which is not a theory is logically not explicable. The specificity of verbal allegations about the world does not result from the fact that statements describe experiences in a world of given specificity but from the specificity of language itself in its quality as a theory of the world which like any other theory can generate only its own statements. The above mentioned ontological implications of ordinary languages as comprised in our world picture, therefore, are not extensions of an otherwise neutral language which one could eliminate where necessary. Language itself is genuinely a theory. Consequently no general criteria could be established to identify the ontological premises of a theory as proposed by Stegmüller (1969) and other representatives of analytical philosophy, in order to deliberate theories from unrecognised and usually unwanted implications. The critical and very presuppositions of a theory are already embodied in the language applied and its logical structure. What we called the (genetically inherited) Ur-theory is the ontological presupposition of any classical theory. The intention to clear languages or theories of their ontological presuppositions in order to come to a neutral description of nature is based on the idea that the specificity of all description is grounded in the specificity of the objects concerned rather than in the specificity of the describing tools themselves, i.e. it is based on realism. Realism and the idea of ontology-free-languages or theories are equivalent.

Also mathematics have to be seen as a language we use to describe certain specificities of our perception. In this respect mathematics can be as little neutral as ordinary language. Just as with language, mathematics derives its specificity from the cognitive operators which operationalise mathematical terms. So, mathematics can express only special statements. As the constituting operators are inborn and more or less equal for all men, it seems evident for us that their invariants are universal entities. Here, even more than with the categories of our perceptions, it is difficult to understand that the elementary notions of mathematical and formal thinking are purely human specifica. It is rather a very intuitive view that there is something such as a notional reality, sometimes called a Platonic reality.

If we start from the suggesting idea that operators constituting the structures of mathematics and of sensory perceptions (for phylogenetic reasons) are related to each other, then the mathematical structures and the sensuously perceived structures themselves must show similarities. This would explain why mathematics does so well in describing the regularities we perceive, or why the world, as Davies asked (1990), is algorithmically compressible (i.e. why the world despite all its vast complexity can be described by relatively modest mathematical means, or, in other words, why induction is so successful): the physical world—which is the world of our perceptions—is itself, on the ground of its mental genesis, algorithmically structured. Perceived regularities and mathematical structures are phylogenetic homologa. This is the reason why the formulation of (physical) theories in terms of the mathematics we are acquainted with is an essential prerequisite for their capability to emulate the genesis of perception and, therefore, for their truthfulness. From the classical point of view (i.e. within the theory of reality) the algorithmical compressibility of the world or, what is the same, the success of induction cannot be explained.

But what, then, are the specifica which mathematics and the world of our perceptions have in common so that the two areas can consider each other as their successful theories? This is difficult to say as we have to abstract just from these specifica, what is possible only if they themselves do not belong to the most primitive elements of our thinking. The following might give a clue: to the very beginnings of our inborn ways of thinking belongs the fact that we use the same kind of cut by means of which we separate ourselves from the outside world, we use to separate the outside world itself into single subjects to each of which we attribute an independent identity. This approach is not compulsory. Quantum mechanics shows how the entire (physical) universe can be seen as a unity which can be described by a single wave function. Each division of the universe into subsystems is a matter of the categories applied and, therefore, is arbitrary as phylogenetically acquired categories are not determined either. Our inborn category of identity allows us to separate systems into discernible entities. It is, therefore, constitutive for the notion of plural (and, therefore, for the notion of set) as well as for the notion of cardinal numbers.

A second clue concerns the relationship between the metrics of space and numbers. According to what Piaget (1970: 58) found with children, it is not the category of space which allows us to define motion as mapping a line in space to the scale of time. It is rather motion which generates the category of spatial structure. The most primitive intuition, as Piaget called it, is not space but motion. Just as it is impossible to go from one number to another without a counting (or equivalent) operator, we cannot distinguish points in space except by attributing them to a path of motion. Counting and moving are analogue terms within the genesis of homologue algebraic and geometrical structures. It is this homology which allows us to extrapolate the observations of motional phenomena in an empirically verifiable manner. The continuity of any physical motion for example is a cognitive phenomenon, i.e., it is part of our metaphysics, and not the consequence of an independent law of nature. Formulating discontinuous motions would require a spatial metric which, on the other hand, is only defined by means of the category of motion itself. Discontinuous motions, therefore, cannot be realised within the human cognitive apparatus, i.e. within our metaphysics. By this, the degrees of freedom of actual motions are drastically reduced. The same applies for the compactness of numbers we use to establish metric spaces and (regular) analytical functions in metric spaces. Discontinuity of a set of numbers is defined only within the context of a previously defined metric. So, numbers generated by a metric defining (counting) operator are compact per se. Analytical functions in metric spaces are, therefore, born candidates to describe the phenomena of mechanics. This altogether strengthens the assumption that what Davies called the *algorithmical compressibility* of the world is essentially based upon functional homologies between the mental roots of perceptual and mathematical procedures.

The close relationship between spatial perception and mathematics can also be seen from another example: spatial coding of mathematical notions also from areas outside geometry is probably the very beginning of mathematical heuristics. This means the visualisation of sets as a closed figures with points inside representing the set's elements as well as seeing ordered sets as spatial chains. The same applies to the basic notions in topology such as 'exterior', 'boundary' and 'interior' points, 'isolated' points, etc. Even the notion of cardinality of sets comprises a certain geometrical coding. The cardinality of sets cannot be defined operationally as the process of counting or mapping in pairs requires that the elements concerned differ at least in one property defining their identity (for example in their position with respect to the counting device). You cannot 'pick out' an element which has not a well defined geometrical position. The same applies to the notion of plurality. That something exists in several but equal copies is plausible only if these copies differ in their spatial position. But we cannot replace position as a identity constituting element by, say, colour: we cannot say that several objects have all properties in common—including position—but not colour.

As already mentioned, CEE requires that not only the regularities we find in sensory perceptions have to be seen as invariants of certain mental operators, but also the regularities we find in logical and mathematical thinking. Indeed, the elementary logical structures and procedures which we find and apply, respectively, in language are phylogenetically based human specifica like the perceptional structures upon which we will apply them in order to generate higher theories. Particularly the laws of logic cannot be explained as universalia in the sense of Leibniz which on grounds of their truthfulness would hold in 'any possible world'. This view is implicitly held, for example, by Vittorio Hösle (1988) when he wrote that *the statement S there is no synthetic a-priori is obviously itself an a-priori statement. So S contradicts itself and its negation, therefore, must be true*. There are, of course, categories which, for phylogenetic reasons, are used by all men. Logic as a scientific discipline deals with the structures which can be constructed on this phylogenetically established basis which we later on would furnish with empirical and other theories. Konrad Lorenz (1941) speaks of our 'forms of intuition' (Anschaungsformen) which cannot be derived from any individual experience and, therefore, are *ontogenetic a-priori*, but which, however, are the outcome of evolution and so are *phylogenetic a-posteriori*. What we call synthetic a-priori reflects nothing but the inborn human specific ways of thinking which outside this framework cannot even be articulated. What is more, no statement at all can be articulated beforehand and outside the framework of human categories if we want to understand them. So it is impossible to find statements which could be accepted by any sufficiently complex intelligence, irrespective of its phylogenetic background and which, therefore, could be called universal. Even the question if a certain statement expressed by an intelligence A would mean the same as what another intelligence B has formulated, can be replied only if the categories of thinking of A and B can be mapped on each other which, is possible only on the ground of a transformation which necessarily is human-specific as well. In other words, the notion of an universal synthetic a-priori cannot be logically explicated. Statements dealing with the existence of universal synthetic a-priori, as advocated by Hösle, are neither false nor true. They are empty. This is well in accordance with the views of Kant, insofar as there are forms of intuition prior to any experience—but only prior to any individual experience, not prior to any phylogenetic experience. The phylogenetically accumulated experience, as represented in our picture of the world, and the categories of our thinking and perceiving are the result of an permanent co-evolution. The idea that what is a-priori for the individual is a-posteriori for the species was articulated already before Lorenz (1941) by Spencer (1872) and Haeckel (1902). A summary is given by Oeser (1984).

6. EPISTEMOLOGICAL AUTO-REPRODUCTION

Up to now we discussed cognitive evolution at a rather elementary level, i.e., at a level where tools and strategies are required for avoiding collisions when running through forests or for identifying physical objects and their shapes. But our cognitive ambitions aim at higher goals. We want to get theories that explain the sometimes very complex relationship between different phenomena. We want to know the causal structure of the world and we want to discover the physical and biological history of nature, up to the various roads of cognitive evolution—and all this should be the result of cognitive evolution. The question, then, is: Can cognitive evolution help us to understand cognitive evolution?

Here we will deal with the question how to find possible criteria for a successful epistemology when evaluation by an independent outside reality is no longer feasible.

The difficulty we have in accepting the notional character of our experiences as human-specific constructs differs with space and with time. As to the notion of space, undoubted (except perhaps by naive realists) is that the spatial patterns we perceive are not objective in the sense of their being considered views of real structures, i.e., the world is not necessarily what it appears to be. Here, with space, we quite readily attribute to our world view a reduced objectivity. Not so with time: The recorded time topology of events we consider to be real. And so we consider the order of events as we have perceived them. The past is as it was and even God cannot change it a-posteriori, we are used to say. Weizsäcker (1985) called this the 'facticity of the past'. Actually, however, events can only be defined as the results of cognitive or scientific interpretations, just as visual patterns can only be defined as invariants of cognitive operators. Events, as such, have a less clearly defined outlines than visual patterns have. A modification of the interpretations of events used (for example, in the light of a novel theory) may well effect the past. An experiment may have been made in the beginning of this century documenting unambiguously a speed faster than that of light. After the appearance of the theory of relativity, the protocol of the same experiment would have had to be rewritten in using the relativistic formula which would lead to a speed less than that of light. A similar revision would have to be made if evolution would have changed our cognitive operators. But because this has not happened during historical times, the illusion arose of both the facticity of the past and the objectivity of the laws of nature.

The allegation that the historicity of the world is a human-specific artefact is even more problematic as it is based (through CEE) just on what is known about biological evolution, and this deals explicitly with the historical order of phylogenetic events. Said in another way, on the one hand our world view is the construct of our cognitive and experimental apparatus, on the other hand, just this world view is what physics and biology refer to, particularly when describing the development of the human brain and the operators established there. What, then, is hen, and what is egg? Is it the real world we live in and which developed in the course of biotic evolution up to and including the brain's functions, or is it just these brain functions which bring about the view of a real world as a tool for both articulating and solving our problems? Formulated differently, are perceptions brought about by nature, or is nature a category brought about by our cognitive apparatus? This dichotomy is the reason for the frequent accusations which say that EE is circular insofar as not only the categories of space, time and causality are interpreted in phylogenetic terms but also the notion of reality and nature—the latter comprising phylogeny itself. So, phylogeny is interpreted by phylogeny, which is circular.

Actually, however, no real dichotomy exists as long as there is certainty that perceptions and nature condition one another through generating one another. This certainty is provided by the fact that our cognitive phenotype constructs a world picture which permits an understanding of the genesis of just this cognitive phenotype by means of evolution within the framework of just this world picture. In other words, a world picture brought about by human brains has to explain everything from the Big Bang, the creation of our world, organic and then cognitive evolution and eventually the development of the world picture itself, i.e., the cognitive phenotype has to reproduce itself in the same sense the organic phenotype has to do. A cognitive phenotype (or a world picture) which meets this requirement we will call consistent. Accordingly, further to the special cognitive phenotype we have acquired, there is an unlimited number of possible (and consistent) cognitive species similar to the many existing or possible organic phenotypes (i.e. species).

Also biotic organisms are not required to be ‘true’ but rather to reproduce, i.e. (as biologists are used to say) to contribute to the survival of the genes concerned. Thus, not only organic ontogenesis but also cognitive evolution has to be understood as circular, auto-reproductive process in the subsequent sense.

In the biotic area the following holds: the epigenetic system of an organism is what determines how the genome’s structure is to be interpreted and expressed into the phenotype. Identical reproduction is possible, however, only if the epigenetic system brings about a phenotype comprising the epigenetic system itself.

In the cognitive area the following holds: the cognitive apparatus (and all the science based on it) is what decides how the sensory input is to be interpreted and which world view will be conveyed. The knowledge acquired in this manner is consistent and reproducible, however, only if the cognitive/scientific apparatus generates a world view that includes the cognitive/scientific apparatus itself.

A genome on its own cannot determine the phenotype in the sense of providing a ‘blueprint’ it rather represents one of several levels in the process of auto-reproduction nor can the sensory input dictate its own interpretation, and, by this, the reactions it will effect. This limitation does not contradict the fact that, within the context of a given organic or cognitive phenotype having a given interpretative machinery, a genetic mutation as well as a new perception may lead to reproducible modifications of our physical constitution or of our theories. This means that, as long as the epigenetic system remains unmodified, a given genetic mutation will always produce the same phenotypic change; and as long as our cognitive apparatus and our scientific theories also remain unmodified, a given sensorial input will always lead to the same reading. What we have to avoid, however, is concluding that what mutations and perceptions initiate is also what they determine. Determinism is possible only within a given scheme of interpretations, i.e., outside qualitative extensions changing the interpretation concerned. The same limitations hold for adaptation. Adaptation makes sense only as long as there are no qualitative extensions as these will modify the requirements to be met, i.e. the selective pressure. The world seen as the sum total of the boundary conditions of our acting is subject to a permanent actualisation, as acting aims at changing just these conditions in order to make further and more ample acting feasible. This begins with the organic phenotype which defines the constraints for evolutionary ‘acting’, which in turn changes the constraints for further evolution (evolution meaning the evolution of its own boundary conditions). And it ends with the cognitive phenotype that defines, through our world view, which kind of scientific acting is possible due to which the world view itself may be affected—a paradigmatic shift in the sense of Kuhn, so to speak. The world as object of adaptation can be defined only for the time between two 'paradigmatic changes', i.e., between two qualitative extensions.

Circularity, a devastating objection for any theory within the context of classical realism, becomes (in the sense explained here) a necessary prerequisite for any complete constructivist approach. A world view brought about by a cognitive phenotype is consistent if and only if the world concerned enables the genesis of the cognitive phenotype. The role of circularity constitutes the key difference between realism (of whatever kind) and constructivism as presented here. Realism requires of life mastering methods consistency with an independent outside world. A constructivist interpretation of the world as proposed here, however, needs only to reconstruct itself.

(1) The most elementary position taken is that cognitive constructs (perceptions) have to delineate correctly the structures of the environment, since the strategies devised to meet the requirements of the environment are believed to be derivable from those structures. This is the basis for most kinds of *realism*. Physical knowledge is reliable (i.e., it allows verifiable predictions) if and only if it is 'true', i.e. if it is derived from perceptions and their 'true' theoretical interpretations. Both perceptions and true theories are seen to depend on the structure of an external world. Knowledge when being true is irreversible, additive and converges towards a complete and definitive set of laws of nature. The progress of knowledge is based on inductive inference. The success of induction cannot be derived rationally. If epistemology is seen as a matter of cognitive evolution it is understood as 'natural selection epistemology' à la Campbell.

(2) In *radical constructivism* (RC) (Glasersfeld, 1995) as well, cognitive constructs have to contribute to meeting the requirements of the environment, but not necessarily by means of delineating environmental structures but rather functionally. The notion of 'truth' is replaced with 'viability' within the subjects' experiential world. Physical knowledge is reliable (i.e., it allows verifiable predictions) if it is derived from perceptions (or phenomena) which depend on an external world and their interpretation by means of theories which no longer must be true but viable. The progress of knowledge is based on inductive inference. (What succeeded in the past will also succeed in the future.) The success of induction cannot be derived rationally.

A more refined version of radical constructivism is developed by Foerster (2003) and Riegler (2001). Both reject reference to an outside world when using Glasersfeld's term 'viability'. Foerster (2003) argues that what appears to us as objects are equilibria that determine themselves through internal circular processes. Riegler (2001) refers to what he calls 'epistemological solipsismus'.

(3) In CEE physical knowledge is reliable (i.e., it allows verifiable predictions) if it is derived from perceptions and their appropriate interpretation, but neither perceptions nor their (viable) interpretations need the evaluation by an external world. The most elementary prediction, i.e. prediction by means of linear extrapolation, is possible if and only if the development in question is linear in time. For this, it is sufficient and necessary that the phylogenetically acquired observational terms are cyclic variables (in the sense of Hamilton–Jacobi) with respect to the elementary human action operators. This resulted in the metatheory of classical physics, i.e. in the mental notion of time, space, spatial identity, locomotion, momentum, etc., and to the conservation laws of classical mechanics. More sophisticated actions (particularly qualitative extensions) require 'non-classical views', i.e., a redefinition of our notional reference frame, i.e., of what we consider to be an observation or a phenomenon with a direct effect on what we call the laws of nature. The structure of our perceptional world, therefore, will depend on what man can do by natural or technical means and it will change according to possible qualitative extensions brought about by novel experimental development. Knowledge is irreversible, additive and convergent only within quantitative extensions. Outside it will depend on what non-classical metatheory we will use to respond to the qualitative extension concerned. The progress of knowledge within quantitative extensions is based on inductive inference. Induction succeeds because and as long as we describe the 'world' in terms of cyclical variables. An epistemology comprising the notion of time and development in time is consistent if it can explain its own genesis, i.e. if it is circular. So we can say:
   - The main specialty of CEE as opposed to RE is that organic boundary conditions have been found that explain important features of our world view.
   - The main specialty of CEE as opposed to classical realism is that the perceived regularities are explained as invariants of cognitive operators, whereas in classical realism they are explained as (structural or functional) pictures of the regularities of a real world.

7. CONCLUSION

We have seen that the laws of nature we use do not describe an objective world. Rather they are a reference frame for analysing our experiences. They depend on our cognitive phenotype (e.g. do we see the world in two, three or four dimensions?) which in turn depends on our organic phenotype (e.g. can we walk or not? Do we have remote perception?). There are many different organic phenotypes (species) which all are successful survivors. Each of them can bring about several different but successful cognitive phenotypes which are characterised by their specific sets of natural laws. Measurement and other physical devices can be considered as artificial extensions of our organic phenotype. This may modify the set of possible cognitive phenotypes. This happened when experimental evidence forced us to replace our classical world view by the quantum mechanical world view. Similar may happen again and again.

From this we can conclude: The structure of an independent outside world cannot provide the boundary conditions for cognitive evolution (in the sense of Campbell's natural selection epistemology) as this structure itself is the outcome of our cognitive phenotype. The only possible source is our organic phenotype. The organic phenotype does not determine the cognitive phenotype but it provides the boundary conditions for its evolution. The same applies for the various hierarchical levels in organic evolution. None of them determines the next higher level but it provides the boundary conditions concerned (or the genetic burden as Rupert Riedl says). Under this aspect cognitive evolution is nothing but a new level in man's evolution.

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Is the real world something more than the world of our experience? Relations between Neo-Darwinism, transcendental philosophy and cognitive sciences

Adrianna Wozniak

Faculty of Philosophy, University of Lyon III, France; Faculty of Philosophy, University of Wroclaw, Poland and Institute for Cognitive Sciences, CNRS, France
wozniak@isc.cnrs.fr

Abstract

The question I will deal with concerns the nature of phylogenetically acquired knowledge and the assumptions of biological evolutionary epistemology. EE constitutes a direct extension of the synthetic theory of evolution and supposes that (1) some external world exists and (2) knowledge about the external world has been shaped by the external world itself, i.e. through natural selection.

If evolutionary epistemology accepts the evolution as a fact and admits the influence of the natural selection on the formation of living organisms (including their cognition), the speculations of constructivism and of subjective or transcendental idealism are not defensible.

The ontological status of logic and mathematics will be discussed from an evolutionary point of view as well.

1. INTRODUCTION

The understanding of the living world that the synthetic theory of evolution offers determines the assertions of biological evolutionary epistemology[1] about the nature of phylogenetically acquired knowledge. The Modern Synthesis has monistic and materialistic assumptions and supposes that natural selection, based on evolutionary constraints (Gould and Lewontin, 1994), shapes organical forms. The action of natural selection concerns inborn cognition as well. What kind of assertion, then, does the biological evolutionary epistemology (EE) set forth about the nature of knowledge, given that it aspires to agree with today's theory of evolution? First of all, EE treats organic cognition as corresponding to the external world. This is the case principally because natural selection, which is embodied by outside influences, shapes organic cognition. It

[1] I will discuss about evolutionary epistemology of mechanisms and not about evolutionary epistemology of theories (Bradie, 1986).

N. Gontier et al. (eds.), Evolutionary Epistemology, Language and Culture, 95–108.

implies directly that a given organism's cognitive abilities, which were formed in the phylogenetic past, constitute a response to the surrounding conditions of the organism, i.e. to the external world. Knowledge about the outside world comes into existence in the cognitive apparatus of living organisms, being shaped by the external world itself. Consequently, the external world is mirrored in organic knowledge. Obviously, for EE, some external world exists. Those assertions of EE naturally follow from the monistic and materialistic metaphysical suppositions of the Modern Synthesis, which is based on the conviction that natural selection has a direct influence on organic constitution.

There are tight connections between the way we consider the nature of the world and the nature of knowledge. This means that idealistic or constructivistic assertions make no sense from today's evolutionary theory perspective. Unless the constructivists succeed in proving that natural selection has no direct influence on living organisms' physical constitution (which is tantamount to contesting the very fact of evolution), their thesis that cognitive features are free constructions of organisms themselves, and that cognitive forms do not depend on natural selection's brushwork, is not defensible. A similar idea appeared in the idealistic philosophical current. Although constructivism is a contemporary speculation and idealism (subjective idealism as well as transcendental idealism) goes back to 18th century, they have two assumptions in common. The first assumption stipulates that (1) there is no relation between the external world (things which exist independently of the mind) and cognition (things which exist in the mind). The second assumption follows from the first. If (1) the evolution of cognition is not connected at all to the external world, then (2) even if our cognition tells something about the external world, we can only be sure that it tells something about our cognition. We have no right to extrapolate what our cognition tells to the extra-subjective world and to pretend that it effectively tells something true about the outside world. Thus, cognition is valid only when applied to the cognitive dimension. There is no justification to transcend it and extend it to what is beyond and belongs to the outside world. What is more, we do not even need to suppose the existence of the outside world. However, if biological evolutionary epistemology accepts the evolution as a fact and admits the influence of natural selection on the formation of living organisms, it is not possible to defend constructivist conclusions.

2. THE NATURE OF REALITY ACCORDING TO THE SYNTHETIC THEORY OF EVOLUTION

2.1. Monism and Materialism, Continuity of Living Organisms

The synthetic theory of evolution gives us an understanding of the living world, its dynamics and nature. The vision of the world that the Modern Synthesis offers has the marks of metaphysical inquiry, of which the first aim is the most general investigation possible about the nature of reality. On the Modern Synthesis view, everything interacts with everything else, it is a kind of variabilism *à la* Heraclitos. This vision is monistic and rests on the metaphysical supposition of a single ultimate principle: matter.[2] The Modern Synthesis postulates the unity and continuity of the living world. This continuity is underpinned by the homogeneity of living beings, based on the same material nature.

For instance, hereditary continuity rests on material, physical continuity. Genetic information exists in the sequence of nucleic acids and has no existence apart from its support, the vehicle which constitutes it. Cellular information or signal means nothing more than chemical molecules and their action: this is the way that cells exist—detecting, converting and exchanging molecular components. This constant interaction and communication underpins the process of life.[3] Signal and information are physically transferred from the surface of a cell to its other parts. This ability to communicate, interact and exchange is what the cell actually is: if a cell could not receive or respond to signals from its environment, nothing would be left of it. Communication and exchange have allowed cells to evolve: if they had not existed, cells would have no *food*, could not *avoid predators*, i.e. would be unable to survive, especially since competing cells exist which can and do communicate—produce, recognise, interpret and answer to signals from the environment. Transduction of signal—i.e. of information—means that a message is converted from one form to another and its original content is retained.[4] The inter- and intracellular signalling, converting and communicating of molecules translates a signal into a particular cell behaviour. But the information or, rather, content itself is nothing but the components, which physically structure and vehicle it, and which are sort of building block constituents for information. There is no substantial existence beyond that.

2.2. Metaphysical Unity of Mind and Body, of the Knowing Subject and the Object of Knowledge

In the same way, the scientific view of the soul and mind (consciousness, free will etc.) conceives it as being a manifestation of the physiology of the brain

[2] Two major tendencies in metaphysics are idealism (considering reality to be spiritual or mental) and materialism (considering reality to be material). They both propose a single ultimate principle, and both are monistic. Metaphysics → monism → idealism—Berkeley versus Materialism and Modern Synthesis.

[3] Receptors respond to mechanical forces such as touch, pressure, vibration, to temperature changes, to chemical molecules, to painful stimuli which may be damaging to tissues, to light.

[4] Let us take the famous example of a message sent by telephone: one person speaks into a transmitter which converts the sound into an electrical signal. Next, the electric signal is transmitted over distances and then is converted back into sound at its destination. The original content of the message is retained.

and nervous system, an effect of physical reality, organic constitution. In 1994, Crick published his book, *The Astonishing Hypothesis: The Scientific Search for the Soul*. Francis Crick's (1999: 3) Astonishing Hypothesis is that:

> a person's mental activities are entirely due to the behaviour of nerve cells, glial cells, and the atoms, ions, and molecules that make them up and influence them.[. . .] You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behaviour of a vast assembly of nerve cells and their associated molecules.

Mind and body are part of the same reality. The brain is not a seat for the soul, which is said to function independently of it and of the environment. The brain by its constitution is an organ of exchange, a big window towards and from the world, including the external environment (extra-subjective world) as well as the internal environment (body and senses). The Modern Synthesis withdraws from the dualistic theses inherited from Descartes' distinction (Descartes, 1992) of the two ontological categories of which reality consists, namely the dichotomy of *res cogitans* (thinking things, mind, soul) and *res extensa* (extended things, body). Without making a distinction between cognitive subject, ego, mind, soul, etc., and the external, real world, another apparent ontological distinction seems to be suppressed in the Modern Synthesis: the one between the knowing subject and the object of knowledge. Subjects and objects are defined in a conventional, arbitrary way.

3. A COMMON STARTING POINT: WHAT IS PERCEIVED BY OUR SENSES EXISTS

The cognitive contents of a given perception have the same nature as its components: it is the same thing but seen at different levels of generalisation. We can say that the senses and their cognitive contents are a single thing taken from a single world. This is because perception is a constant flow and an exchange between all parts of an organism, and because there is a tight relation between senses, bodies, sense data and states of mind, impressions, imprints that the world makes through the senses. That is why it seems justified to assert that our senses inform us about the existence of things outside the perception of an organism. On one point, the Modern Synthesis would agree with George Berkeley's subjective idealism, namely that what is perceived exists, that what is in our senses exists. Nevertheless, for the Modern Synthesis, as what is in our senses is the same thing as what is outside our senses, what exists in our senses is existing as what is outside them.

4. DIVERGENT CONCLUSIONS

If we were to remove the dualistic suppositions from Berkeley's argument, it could prove materialism (not idealism) and the existence of the real world (and not only the existence of the soul and of God). The Modern Synthesis uses Berkeley's argument to prove the contradictory claim that it was conceived for proving: namely, monism (if not materialism at once), and the existence of the real world.

We can concisely draw a parallel between Berkeley's argumentation and what follows from Modern Synthesis metaphysics (Table 1).

The Modern Synthesis would agree with George Berkeley's subjective idealism that what is perceived exists, that what is in our senses exists, and this argues for materialism and for the existence of the real world. Thus, the Modern Synthesis presupposes metaphysical realism, while Berkeley postulated that external things do not exist.

The same type of reasoning, but from the perspective of evolutionary time, applies to the inborn cognitive representations acquired in the phylogenetic past of an organism:

(1) There is a tight phylogenetic relation between stimuli from the surrounding environment and the form of their cognitive inborn representations;
(2) Thus, our inborn cognition informs us about the external phylogenetic environment.

5. PURE FORMS, EMPTY FORMS?

According to Berkeley (1991), a representative of subjective idealism, in trying to seize the existence of things in themselves, we conceive nothing but our own ideas. This argument was undermined by Berkeley's successor, Immanuel Kant, who contended that things in themselves are independent of our experience of them, so that we know absolutely nothing about the noumenal realm. Nevertheless, the appearance and the phenomena given in our experience imply that there must be something which causes them. Even if this appearance does not give us access to the nature of the thing in itself, at least it guarantees that there is some thing in itself.

According to Kant, we know how the world appears to us, how the world looks to our cognitive system, but we do not know how the world is in itself. Kant's argument to prove transcendental idealism is that we cannot conceive of the properties of things in themselves until we conceive of things in themselves which those categories (properties) describe (Kant, 1980). These categories, which belong to things in themselves, cannot be intuited prior to the things which they define. Nevertheless, these categories are intuited a priori.

Table 1. The subjective idealism of Berkeley (and later of constructivists) and biological evolutionary epistemology, derived from Neo-Darwinism. The same starting point but with different presuppositions that leads to the contradictory conclusions about the existence of the external world and its nature. For constructivists, as for Berkeley, there is no relation between things in themselves and their representations ➔ we cannot (nor do we have a need to) prove the existence of the external world nor the reliable relation between things in themselves and the contents of experience, representations or ideas

G. Berkeley (and later constructivists)	Modern Synthesis ➔ biological evolutionary epistemology
Assumption: Dualism, distinction between body and mind.	Assumption: The content of perception has the same nature as the components of perception
No relation between —things which exist independently of the mind and things which exist in the mind —between bodies and our ideas about them —between senses, external things and the soul, ego—seat of impressions	Perception is a constant flow and exchange between every parts of the organism and its environment
➢ Our senses inform us only about impressions, about what is being directly perceived by senses ➔ And only about this, can we say that it exists (and that it exists only in senses, *esse est percipi*) ➢ Our senses do not inform us about the existence of things independent of the mind ➔ We have no right to believe that things in themselves exist on the basis of sense data	Our senses inform us about the existence of things outside of the perception.
Trying to grasp the existence of things in themselves, we conceive nothing but our own ideas. The existence of the world as existing independently of the mind is postulated through the rules of rational inference from sense data Conclusions: ➔ External things do not exist and because there is no necessary relation between bodies and our ideas about them, we do not need to suppose that the external world exists ➔ subjective idealism	Conclusions: If what is perceived exists (*esse est percipi*) ➔ what is in our senses exists ➔ metaphysical realism: the outside world exists

What is more, every cognitive act passes solely through these categories. That is why they can represent only the way that things appear to us, and not things as they are in themselves.

Kant argues that concepts of understanding are pure forms of intuition because they precede and structure all experience. Perception is always a judgement, which goes beyond what is directly given in experience. There is no direct relation between the input data from the external world and our representations of it. We do not perceive things in themselves but sense-data: perception is mediated and is an indirec representation of the world. So, on the basis of the apprehension of how things appear to be, on how they look (for example when we see them—on the basis of their visual appearance), can we assert that we learn how things are in our immediate environment? Can we transcend our experience?

6. DO WE KNOW ANYTHING BEYOND OUR OWN EXPERIENCE?

EE claims that categories of cognition are embodied in physiological make-up and convert sensory data into perception. They are constant and invariant. Thanks to this, we perceive regularities. Our inborn cognitive categories, our cognitive organic make-up, formed by natural selection in the evolutionary past, constitute the sensory input as well as the external stimuli and participate in the modification of our representation. EE also claims that we perceive the world indirectly, in the sense that our cognitive apparatus converts the input from the external world. But for EE, *indirectly* means that the input passes through complex steps and levels, and not through some metaphysical gate to a qualitatively different existence.

Let us come back now to Berkeley's argument, which says that we have no right to infer the existence of the external world from sense data, because the only thing we can assert in a justified way is that there exists what is in our senses. This argument undermining realism assumes that our statements go beyond the data. How then could EE defend realism? EE, derived from the Modern Synthesis, does not represent extreme realism, because here perception does not depend only on the structure of the external world. EE does not represent radical constructivism either, because perception involves the existence of the external world and needs its evaluation through natural selection.

7. ADAPTATION AS A GAIN OF KNOWLEDGE

To live means to interact and to interact means to know, because some kind of knowledge is contained in organic structure. The gain of organic knowledge constitutes an adaptation, it means that certain dispositions, determined by the sequence of nucleic acids, increase the chances to acquire energy or reduce the risk to loose it. These dispositions are hereditary in nature and are originally generated by random mutations. What we call knowledge and adaptation is precisely the alterations introduced in the organic constitution and selected for (Lorenz, 1975: 32).

Nevertheless, we should not forget that the Modern Synthesis is not adaptationism. Not every trait of organism is considered an adaptation

8. HOW DOES NATURAL SELECTION WORK AND WHAT IS THE NATURE OF KNOWLEDGE?

The crucial point to understand is that natural selection eliminates only what is unfavourable and saves what is either beneficial or neutral. This has two major consequences.

8.1. Truth Means Consistency with the Surrounding World Because It Allows to Avoid the Sieve of Natural Selection

The cognitive phenotype is required to be true to the same degree as it is consistent. Truth and consistency are equivalent in the sense that if an organism lives, interacts in such a way that it can spread its genes, it means that the organism comes within the scope of what exists apart from it, outside of it. Since we admit that no organism lives in a void, truth becomes the minimal condition for being invisible and avoiding the sieve of natural selection.

8.2. Impossibility of Entirely Free Constructions

In fact, part of our inborn cognition has evolved phylogenetically and has nothing to do with adaptation to the structure of the world. Thus, there is a considerable number of possible organic (cognitive) phenotypes, which are invisible for natural selection.[5] Nevertheless this number is not infinite. Our inborn epistemology could evolve in many, but not in every direction. Evolution has its narrowing constraints (Gould and Lewontin, 1994) not every form is possible in evolution. Thus we cannot assert, like constructivists do,

[5] The lack of adaptation does not exclude the conservative action of natural selection. Natural selection does not equal adaptation.

that what our cognition submits to us is the result of a process of entirely free construction.

9. PHYLOGENETICALLY ACQUIRED COGNITION IS CONSTRUCTED AS MUCH BY ORGANISMS AS BY THE ENVIRONMENT

Organic knowledge is, on the one hand, an internal item, constructed, created and determined by the cognitive apparatus of a perceiver. On the other hand, the nature of the external world delimits and evaluates the possibility and quality of cognitive items. Cognition emerges from interaction with the environment: an organism influences its environment, and the environment influences it. Cognition is an active, dynamic process. The internal logos are not a static given. Organisms live, change and acquire new qualities and knowledge.[6]

Perception and cognition depend on both:

(1) On the one hand, on the constitution of the organism, on its organic make-up. Potentially, in the same conditions and with the same selective pressures, a number of different forms and different representations are possible. Nevertheless this number is not infinite, as was said earlier (see point Section 8.2).
(2) On the other hand, on the evaluation of the external world through selection. Cognitive forms which are favourable for their bearer are retained by natural selection and their number increases. Cognitive forms which are neutral are retained or rather are not eliminated by the action of natural selection. Cognitive forms which are unfavourable or detrimental for their bearers are eliminated.

Both factors—organisms themselves (as constructivists claim) as well as theirs environments (as realists assert)—equally determine the nature of cognition.

10. BACK TO THE ORIGIN OF THE PURE CATEGORIES OF KNOWLEDGE

For constructivists (and idealists, like Berkeley), there is no relation between things in themselves and the representations of them (or the ideas in Berkeley's

[6] It is also obvious that human cognition is greater than the knowledge of a bacteria and that the progress of phylogenetically acquired knowledge takes place in the evolutionary process, that organic evolution and evolution of cognition are progressive by nature.

sense). We cannot and we do not need to prove the existence of the external world or the reliable relation between things in themselves and the content of experience, of representations or ideas. However, as it has been shown, this argumentation is based on dualistic suppositions about an ontological difference between the knowing subject or mind and the object of knowledge or body, which is rejected by the monism of the Modern Synthesis. On this view, one question—that need not be asked for constructivists—should be reinstated. It is the question of origin: how did the Kantian synthetic a priori come into existence? How does the structure of nature print itself on the internal structure of cognition of organisms? To use Heraclitos' terms: what is the relation between the universal logos and our own internal logos?

The sensitive point lies in the origin of these categories. Solipsists and constructivists meet again on Kant's point that concepts of understanding are pure forms of intuition because they precede and structure all experience. Our forms of intuition, our categories of understanding, the forms of 'logical functions of judgement',[7] the necessary conditions to conceive of any objects, which Kant defined as synthetic judgements a priori, are true and universally valid without being analytic or derived from experience.

11. THE ONTOGENETIC A PRIORI IS PHYLOGENETIC ACQUIRED KNOWLEDGE

In the Modern Synthesis, the question of origin was clarified as follows: the ontogenetic a priori is phylogenetic acquired knowledge. It implies that a priori truths are not purely analytic but are full of empirical significance. For the Modern Synthesis, *the pure forms of intuition* are also prior and constitutive for any cognitive act, but they are neither necessary nor universally valid. They are innate, as they were for Kant, but today *innate* means innate in an ontogenetic perspective, and acquired in a phylogenetic perspective.

Our cognitive system is explained precisely as a product of the evolutionary process. Thus, cognition is considered an adaptation it is claimed to fit the real world that cognitive structures reflect, it is supposed to be isomorphic, homomorphic, conform, congruent, convergent and at least partially correspondent with the outside world. We find in Konrad Lorenz's writings: "*the categories and modes of perception of man's cognitive apparatus are natural products of phylogeny and are adapted to the parameters of external reality in the same way, and for the same reasons, as the horse's hooves are adapted to the prairie, or the fish' fins to the water*" (Lorenz, 1975: 37).

[7] According to Kant, knowledge is always expressed in a judgment.

12. IF MATHEMATICS HAS AN ORIGIN (IT IS JUST ANOTHER OBJECT OF THE EVOLUTIONARY PROCESS), THEY ARE NOT OBJECTIVE, ABSOLUTELY UNIVERSAL AND MIND-INDEPENDENT

The knowledge, including logical knowledge, is not merely a product of adaptation: the laws of logic and mathematics are aspects of the law of adaptation itself, they emerge naturally from evolutionary processes, in which they are fully implicit. Logical laws are not just the product of historic evolutionary processes. They themselves are an intrinsic part of this process; they are constituents of this very process.

Organisms' reasoning is not just a product of the evolutionary processes. If this were so, we would be back to the old question of where the laws of logic come from, already posed by Plato, who presumed that some kind of rational heaven existed, which he called Pleroma, but never described in details. According to the Modern Synthesis, the laws of logic or mathematics are neither pre-existent nor independent. They are identified with the evolutionary processes themselves.[8] It is not just that the evolutionary pressures shape an organism to a pre-existent, independent, extra-subjective realm and that the organisms simply obey external logical conditions. They engender the rules of logic or mathematics: they are these rules. For Kant, the most basic laws of nature, for instance the truths of logic or mathematics represent the systematic structure of the world of our experience, they are true for the phenomena, but do not say anything about noumena. Nevertheless, for the Modern Synthesis, those rules of logic or mathematics are manifestations, expressions of the matter. Logic, mathematics and knowledge generally are nothing but the effect of the action of matter and have no existence of their own, independently of their material vehicles.

According to the Modern Synthesis, the nature of knowledge is immanent, because knowledge is contained in a being and results from the very nature of that being. The nature of living beings is supposed to be materialistic, so knowledge can exist only with a materialistic support.

In this context, phylogenetically acquired knowledge which includes the rules of reason can be identified with the way it is manifested: i.e., with behaviour. What we can observe is that certain *external* (in relation to the subject) conditions interact with *internal* conditions of the organism itself. For unicellular organisms, like bacteria, the distinction between the inside and the outside is simply defined by a membrane (for example, unicellular organisms). It has been said that specific stimuli entail aspecific response and

[8] See William Cooper's thesis (Cooper, 2001) that the principles of pure reason are propositions about the very evolutionary processes, indeed evolutionary laws.

adapted behaviour. This is precisely the manifestation of logic; this is what is behind the notion of logic we use. As was mentioned about the ontological status of information, logic exists in the very organic structure, and can be identified with the physical constitution of which it is made up.

Because we share a great proportion of genetic inheritance with the realm of animals and plants, to some degree logical and mathematical rules evolved commonly during the evolution of plant, animal as well as human cognition. Let us consider the basic logical rule of inference, the basic law of thought: *modus ponens* (if the first, then the second; but the first; therefore, the second). This principle can be associated with the basic processes of homeostasis generally observed in the living world, and among others in the earliest forms of life, namely feedback loop processes.[9] The latter describe information processing in nature and can be metaphorically regarded as a kind of cognitive process, i.e. the acquisition of some information, of some objective knowledge.[10] It takes place even at the basic level, as in the case of simple stimulus–response relation.

So *modus ponens* and feedback loop processes can describe for instance how bacteria are able to manage in their mezzocosmos by responding to differences of stimulus intensity. The search for food and the avoidance of dangerous molecules of *Escherichia coli* consist of an alteration: run/tumble (Dusenbery, 1996: 68). Thanks to just one sensor and the ability to change its position, *E. coli* can *infer* the concentration of some substance. The search strategy is the following: if conditions improve then move in some direction, keep going. If not, try a new direction through tumbling. When the concentration of glucose increases, *E. coli* reduces the number of *tumbes*. If there is no glucose or in the presence of benzoate, which is a repellent, the rotations of the flagella are more frequent, which makes the bacterium tumble and, therefore, go in a new random direction.[11]

Knowledge, for instance logical knowledge, is immanent, intrinsic in relation to the matter with which it can be identified. There is no essence behind its laws. Since we know the evolutionary origin of universals, categories of cognition etc., we know their nature: not absolute, not necessary local optimisations. We also know their extension: they exist in human, in animal, in every

[9] Feedback loop process—where the output of a system causes (positive or negative) changes to the system. If the output becomes too great, it acts through the feedback loop to reduce itself.

[10] Konrad Lorenz's example of Paramecia, showing that its reaction to the external stimulus and its movement mean that this Paramecium possesses objective knowledge about the real world (Lorenz, 1975: 12).

[11] We can multiply examples: when Caulobacter is in a wet environment, it is fixed to the ground. But if the weather is continually dry, the bacteria reproduce and develop a flagellum, which enables them to move to a wetter environment.

living organism, as we share genetic inheritance and organic cognition. So the laws of nature, the laws of logic and mathematics are what is invariant and constant in cognitive make-up. They are not objective, absolutely universal, mind-independent but specific to humans and other living forms on the Earth. Truth, in the classical Aristotelian sense, as a coincidence of a representation with reality, is impossible, because the representation exists in some organism. It is not external, objective, independent of how and in what it exists. Perceptual content is intrinsically an experience of some perceiving apparatus, is necessarily from some perspective and is determined by the very organic organisation of a given perceiving subject. Yet, reality still has its independent ontological status.

13. ONE CONSTANT OF THE MODERN SYNTHESIS: VARIABILITY

The Modern Synthesis does not work in essentialist terms as substance and accidental attributes.[12] This view is free of the search for an essence, for a first cause of everything. The accidental does not imply the necessity of existence of the essence. There is no need to search for the essence in what is accidental. The variability and temporality of what appears to our cognition is worth as much as the eternal and immutable essence, whose ontological status is uncertain. The ultimate basis of reality, the constant we would research in the principle, in the essence underlying the universe, is precisely in that incessant variability: this is the only constant. Nevertheless, it would be quite an astounding and stunning thing to replace the very notion of essence.

14. CONCLUSION

We can see that there are tight connections between the way that we consider the nature of evolution, the nature of the living world and the nature of knowledge, between the synthetic theory of evolution and biological evolutionary epistemology. According to how we comprehend the nature of natural selection and its role on modelling organic forms of cognition, evolutionary epistemology can go the way of metaphysical realism, or follow the trail of constructivist speculations. Nevertheless, if evolutionary epistemology claims to agree with the synthetic theory of evolution, it cannot defend and follow the second way.

[12] (essence/accident—lat. per se/per accidens).

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Universal Darwinism and process essentialism

Derek Turner

Department of Philosophy and Goodwin-Niering Center for Conservation Biology and Environmental Studies, Connecticut College, New London, Connecticut, USA
derek.turner@conncoll.edu

Abstract

Daniel Dennett has claimed that 'nothing complicated enough to be really interesting could have an essence'. He and other universal Darwinists hold that Darwin's theory undermined traditional essentialism in biology. This paper shows, first, that Dennett and other universal Darwinists are themselves committed to an essentialist view about historical processes, and second, that this process essentialism is optional. One can be a universal Darwinist without being a process essentialist.

1. INTRODUCTION: THE DARWINIAN REJECTION OF ESSENTIALISM

Daniel Dennett compares Darwinism to a universal acid that dissolves every container and "*eats through just about every traditional concept [...]*" (1995: 63). According to Dennett, one of the many traditional views that Darwin's dangerous idea "eats through" is essentialism, or the view that a member of any species or kind has both essential and accidental properties. The essential properties are what make it the kind of thing that it is. It shares those essential properties with every other member of the species, but not with any non-members. Within the species, the accidental properties may vary. Species essences are immutable. Thus, an essentialist might wish to say that having one hump is an essential feature of dromedaries. All and only dromedaries are camels with one hump. Being a camel with one hump is *what makes* this animal a dromedary. Of course, there is plenty of intraspecific variation; not all dromedaries are exactly alike. However, this intraspecific variation concerns accidental properties.

One might wish to think of the distinction between essential and accidental properties in terms of possibility and necessity. To say that having one hump

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is an essential feature of dromedaries is to say: 'Necessarily, all dromedaries have exactly one hump'. Here the basic idea is that an essential property of a species is a property that no member of that species could fail to have; an accidental property, on the other hand, is a property that one could fail to have and still be a member of the species.

Darwin's idea 'eats through' traditional essentialism in the following way: According to Darwin, existing populations of camels, both dromedaries and Bactrian camels, as well as humpless llamas, are all descended, with modifications, from a common ancestral population in the not so distant past. There is no point in this evolutionary process at which we can say, 'Aha—*That* animal is a dromedary, although its grandparents were not'. Nor is there any point in time at which we could say 'Aha—*now* we have a population of one-humped camels, whereas before we did not'. Species evolve.

If Darwin's theory is a universal acid that 'eats through' traditional essentialism, we might well expect universal Darwinists to take a strong anti-essentialist line, and that is exactly the pose that Dennett strikes:

> Even today Darwin's overthrow of essentialism has not been completely assimilated (1995: 39).

> Nothing complicated enough to be really interesting could have an essence. This anti-essentialist theme was recognized by Darwin as a truly revolutionary epistemological or metaphysical accompaniment to his science; we should not be surprised by how hard it is for people to swallow (1995: 202).

In this paper, I will argue that Dennett himself is one of those people who has failed to assimilate Darwin's overthrow of essentialism, and that he himself has found it hard to swallow Darwin's anti-essentialist theme. I will show that today's 'universal Darwinists'—including David Hull and Richard Dawkins as well as Dennett and many others—continue to buy into a subtle form of essentialism about historical processes.

This *process essentialism* is the view that historical processes come grouped in natural kinds, or that historical processes have essential as well as accidental features. Dennett and Hull both hold that it is possible to specify the essence of a Darwinian evolutionary process by way of the following formulation:

All and only *Darwinian evolutionary processes* have features $F1$, $F2, \ldots, Fn$.

Darwinian evolutionary processes have an essence. Processes of change that occur in biological populations, cultures, economic systems, scientific communities, linguistic communities, and even in the human nervous system during development could all qualify as Darwinian evolutionary processes. What matters is that they share these essential features. Of course, everyone knows—and the universal Darwinists readily admit—that there are glaring differences between biological change and cultural change. These differences, however, concern only the accidental properties of historical processes. The differences have to do with the matter or substrate of those historical processes, rather than the form. What are the essential features of a Darwinian evolutionary process? They are variation, heredity, and differential fitness (Dennett, 1995), or replication, interaction, and selection (Hull, 1988). My thesis, then, is that these universal Darwinists are thinking of historical processes in exactly the same way that a traditional Aristotelian essentialist would have thought about camels, and that there is no good reason for those loyal to Darwin to think of historical processes in this way. I do not claim that Darwinists must, on pain of inconsistency, be anti-essentialists about historical processes. All I want to do here is to show that it is possible for universal Darwinists to be the thoroughgoing anti-essentialists that Dennett seems to think they should be.

2. IS SCIENCE A DARWINIAN EVOLUTIONARY PROCESS?

Long before Richard Dawkins coined the term 'meme', a number of other philosophers and scientists had suggested analogies between biological change on the one hand and cultural, scientific, or intellectual change on the other. For example, toward the end of *The Structure of Scientific Revolutions* (1996), Thomas Kuhn hinted that during periods of revolutionary science, rival paradigms engage in something resembling a struggle for existence within the scientific community, where they compete for the allegiance of scientists. More importantly, though, Kuhn was attracted to the Darwinian idea that the evolutionary process is not going anywhere in particular, that it has no overarching goal or *telos*. Neither, he argued, does science. Although Kuhn's book predates the controversy over punctuated equilibrium, anyone who thinks that biological evolution is punctuated, and that the history of science is punctuated by revolutions, will see an obvious parallel.

It is hard to avoid the thought that there is something fishy about this whole project of drawing analogies between biological evolution and scientific change when we consider that Karl Popper (1972)—whose view of science could scarcely be more different than Kuhn's—also argued that science is a Darwinian process. The process by which novel scientific conjectures are generated, tested, and (usually) eliminated closely parallels the process by which natural selection does its work on new variations in a biological population. If philosophers whose views of science are diametrically opposed both think that scientific change resembles Darwinian evolution, it is hard to know what to conclude: Is one of them badly mistaken about the essential nature of Darwinian evolutionary processes? Are they merely highlighting *different* essential features of Darwinian evolutionary processes? Is each philosopher focusing on only those essential features that conveniently serve his immediate purposes? Either way, it is far from clear how the drawing of parallels between biological evolution and scientific change was supposed to contribute to the resolution of philosophical debates about science.

More recently, Bas van Fraassen (1980) has offered a Darwinian explanation of the empirical success of science, with the aim of countering the realist argument (due to Putnam, Smart, and others) that the success of science would be a miracle if scientific theories were not true or approximately true. In this context, a theory is said to be empirically successful insofar as it yields accurate predictions and enhances our technological control of nature. Van Fraassen suggested that theories had been subjected to a Darwinian selection process within the scientific community, a process that eliminates the unsuccessful ones. Hence, it should come as no surprise that the theories that scientists currently accept are all wildly successful. They are, after all, the descendants of the survivors. Thus, we can explain the empirical success of science without appeal to truth, approximate truth, or reference. Critics (such as Kitcher, 1993) have argued that this explanation should not satisfy anyone. But leaving that aside, I think it is instructive to contrast van Fraassen's proposed anti-realist explanation of the success of science with a very different (but still allegedly Darwinist) explanation proposed by David Hull.

According to Hull, a Darwinian evolutionary process is any historical process that can be analyzed into the sub-processes of replication, interaction, and selection. Hull (1980: 96) defines a replicator as "*an entity that passes on its structure largely intact in successive replications*", and an interactor as "*an entity that interacts as a cohesive whole with its environment in such a way that this interaction causes replication to be differential*". Finally, a selection process is "*a process in which the differential extinction and proliferation of interactors cause the differential perpetuation of the relevant replicators*". If this sounds essentialist, that is because it is.

According to Hull, scientific concepts are replicators, while scientists and research programs are interactors. The central message of Hull's book, *Science as a Selection Process* (1988), is that the differential extinction and proliferation of research programs in science—something which is primarily a social and professional affair—causes the differential perpetuation of scientific theories and concepts. Hull offers an elaborate 'invisible hand' explanation of the success of science: Scientists themselves are social agents pursuing goals such as professional recognition and credit. The classical aims of science—especially prediction and control—are achieved only as a by-product of this Darwinian process by which research programs (roughly analogous to organisms) compete with each other to see who gets to pass on their ideas (analogous to genes).

We have here two potential Darwinian explanations of the success of science. For example, Van Fraassen remains silent about the social interactions among scientists, at least in connection with his explanation of the success of science, whereas Hull thinks that those social interactions must be central to any Darwinian explanation of scientific success. All that I want to remark upon here is that these two accounts of science as a selection process serve entirely different philosophical visions of the nature of science. This alone should make us wonder what sort of philosophical work the analogy is really supposed to be doing.

3. DENNETT'S PROCESS ESSENTIALISM

Daniel Dennett, following Richard Dawkins, takes a Darwinian view of culture in general. Ideas, or 'memes' (= 'discrete memorable units', or 'semantic units') are the replicators of culture, analogous to genes. "*Just as genes propagate themselves by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation*" (Dawkins, 1976: 192). Dennett famously urges us to adopt the meme's eye perspective. From my own perspective, a car stereo is a useful tool for keeping me awake during my morning commute; from the meme's perspective, the car stereo is a useful tool for delivering copies to as many brains as possible.

In the philosophical literature, one finds two very general criticisms of memetics, or what might be called 'cultural Darwinism'. The first is that so far, no one has shown how memetics can be used to generate and test any novel predictions about culture. Many philosophers of biology, in particular, remain skeptical about the whole idea of memetics on the grounds that the friends of the memes have not yet shown that their approach leads to any empirical successes analogous to those of population biology. Memetics looks to many biologists and philosophers of biology like a mere pseudoscience. The first group of critics sees *no useful empirical results*. The second line of criticism is that there are glaring and significant differences between cultural and biological evolution. One disanalogy is that in culture, lineages often converge. For example, Darwin's theory incorporates ideas borrowed from Lyell as well as from Malthus. Another potential disanalogy is that in culture, variation is often directed with respect to selection. When someone writes a new song, that person does so in hopes that the song will catch on and spread through the culture. This second group of critics sees a *weak analogy*.

Dennett (1995) does not seem much bothered by these objections. One reason for this is that his interest in memetics is mainly philosophical, rather than scientific. Since cultural Darwinism is a philosophical outlook, the demand that it produce useful empirical results is unfair. Dennett also concedes that there are significant differences between biological and cultural change. Indeed, the following passage is very revealing:

> There is no denying that there is cultural evolution, in the Darwin-neutral sense that cultures change over time, accumulating and losing features, while also maintaining features from earlier ages [...] But whether such evolution is weakly or strongly analogous to, or parallel to, genetic evolution, the process that Darwinian theory explains so well, is an open question. In fact, it is many open questions. At one extreme, we may imagine, it could turn out that cultural evolution recapitulates all the features of genetic evolution: not only are there gene analogues (memes), but there are strict analogues of phenotypes, genotypes, sexual reproduction, sexual selection, DNA, RNA, codons, allopatric speciation, demes, genomic imprinting, and so forth—the whole edifice of biological theory perfectly mirrored in the medium of culture [...] At the other extreme, cultural evolution could be discovered to operate according to entirely different principles [...]. (1995: 345)

The truth, surely, lies somewhere between these two extremes. Suppose, however, that everyone could arrive at a substantive agreement concerning the actual similarities and differences between cultural and biological evolution. In other words, suppose that both the friends of the memes and their harshest critics could come to agree that biological and cultural evolution have only such-and-such features in common. At that point, all the interesting empirical questions would have been answered. However, there might still be room for a disagreement of emphasis, with the friends of the memes arguing that the agreed-upon similarities between cultural and biological evolution are more important than the differences, while their critics emphasize the agreed-upon disanalogies. (Diagram 1 represents the two axes of potential disagreement here.)

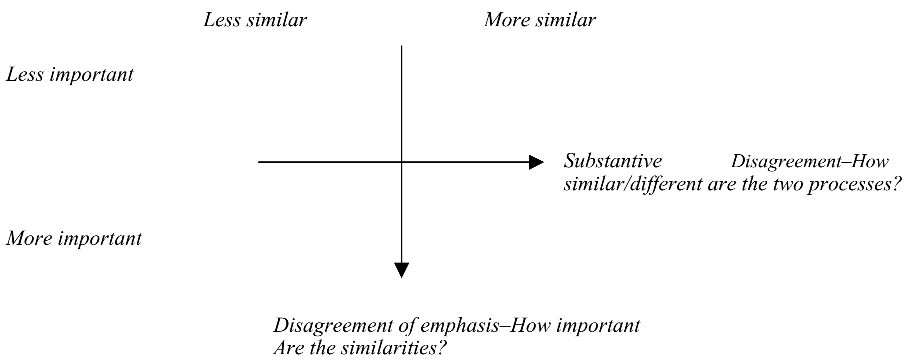

Diagram 1.

How shall we settle a disagreement of emphasis, when it arises in a case where there is substantive agreement about the degree of resemblance between the primary subject and the analog? One way to settle such a disagreement is by appealing to process essentialism: If the shared features of cultural and biological evolution happen to be the *essential features* of Darwinian evolutionary processes, then we may conclude, via the following syllogism, that cultural evolution is a Darwinian evolutionary process:

P1. All and only Darwinian evolutionary processes have features $F1$, $F2, \ldots, F$n.
P2. Cultural evolution has features $F1$, $F2, \ldots, F$n.
Therefore, cultural evolution is a Darwinian evolutionary process.

In other words, one can argue that the agreed-upon similarities between biological and cultural evolution *matter more* than the obvious differences, because those similarities include the essential properties of Darwinian evolutionary processes, whereas the differences between cultural and biological evolution concern merely accidental properties.

One of the more notable claims that Dennett makes in *Darwin's Dangerous Idea* is that evolution is an *algorithmic process*, where an algorithm is conceived of as a function for producing certain outputs given certain inputs. I believe that this construal of Darwin's theory enables Dennett to introduce process essentialism in an intuitively plausible way, without acknowledging that that is what he is doing. Notice, however, that one of Dennett's most interesting claims about algorithms is that they are *substrate neutral*. For example, the addition function can be carried out by a human brain, or by a pocket calculator. Similarly, Dennett argues that Darwinian evolution is an algorithmic process that can be implemented in different substrates—including both biology and culture. It is really surprising that almost 10 years after the publication of Dennett's book, no one has pointed out just how Aristotelian, and just how essentialist, all of this is. The relationship between an algorithmic process and its substrate is just the relationship between form and matter. Aristotle himself would have been quite happy to say that in the cases of Peter, Paul, and Mary, the form (=species essence) of humanity is implemented in different substrates, and that the differences among these distinct individuals are attributable to differences in the substrates. The chief difference between Dennett and Aristotle is a merely accidental one: Dennett is an essentialist about processes, while Aristotle is an essentialist about things.

For good measure, consider once again the work of David Hull, whose commitment to process essentialism is more explicit than anyone else's. Hull basically thinks that all and only Darwinian evolutionary processes are those in which the differential survival and proliferation of interactors causes the differential perpetuation of replicators. If this is right, then *all* he needs to do in order to defend his view of science is to show that scientific change is a process in which the differential survival and proliferation of interactors causes the differential perpetuation of replicators. This syllogism is the linchpin of Hull's argument in *Science as a Process*. Armed with this syllogism, Hull can fend off any critic who wishes to call attention to dissimilarities between biological evolution and the development of science.

Process essentialism is the key to Dennett's defense of memetics. With the syllogism in place, he can insist that for all of the obvious differences, cultural evolution really is a Darwinian evolutionary process, because it possesses all the essential features of one. Moreover, there is no need to point to any predictive or explanatory successes in order to justify the claim that cultural evolution is a Darwinian evolutionary process, because all the justificatory work is done by the syllogism.

4. UNIVERSAL DARWINISM WITHOUT PROCESS ESSENTIALISM

All of the leading universal Darwinists are process essentialists. But process essentialism is (a) a vestige of a pre-Darwinian, basically Aristotelian outlook on the world of living things, and (b) a view which is not—and indeed, could not be—supported by any empirical evidence. In order to explain the biological phenomena (e.g., facts about the geographical distribution of species, or the apparent adaptation of the parts of organisms to their local environments) we need to say something about the actual historical processes that produced the observable effects. We need to say what features those processes actually had, but whether the features were essential or accidental makes no difference to the explanation.

What I now wish to show is that process essentialism is merely optional, and that one can be a Darwinist and even a universal Darwinist without buying into the idea that Darwinian evolutionary processes have an essence. Process essentialism is, in a word, inessential to Darwinism.

What would it mean to completely assimilate Darwin's overthrow of essentialism? I think it would mean treating certain concepts as cluster or family resemblance concepts, much as Wittgenstein treated the concept of a game. Wittgenstein famously argued that no matter how hard we try, we will never be able to come up with a suitable definition of 'game' having the following form:

All and only games have features $F1$, $F2, \ldots, F$n.

Games have no essence. The problem is that any attempt to specify the necessary and sufficient conditions for something is being a game will either include or exclude too much. For example, if we say that a necessary condition for something's being a game is that there be winners and losers, we will have ruled out some obvious examples of games such as Duck, Duck, Goose. But if we say that being a leisure activity is sufficient for being a game, we will have ruled in things like going to the cinema.

It is striking that virtually all philosophers of science have given up on the project of demarcating science from non-science for exactly the same reasons that Wittgenstein thought we should give up any attempt to demarcate games from non-games. So far, every attempt to solve the demarcation problem in the philosophy of science has yielded results that were either too inclusive or too exclusive. Attempts, such as Hull's, to demarcate Darwinian evolutionary processes from other kinds of historical processes face many of the same problems. Interestingly, no one really cares that we are unable to demarcate games from non-games with any precision, and philosophers of science no longer regard the demarcation problem as a legitimate problem. Thus, it is not clear why anyone should care whether we are able to demarcate Darwinian evolutionary processes from other kinds of processes.

An alternative would be to come up with a list of 'family traits' of Darwinian evolutionary processes. These family resemblances might include:

- Speciation
- Changes in the features of populations that can be modeled using the techniques of population genetics
- A struggle for existence
- Differential fitness among variants in a population
- Cumulative natural selection over many generations
- Differential reproduction of organisms
- Differential replication of genes
- Descent with modification
- Variation is undirected with respect to selection
- No overarching goal or *telos*

And so on.

Rather than trying to offer an analysis of the concept of a Darwinian evolutionary process, we can simply say that a process counts as a Darwinian evolutionary process if it possesses *enough* of these family traits. For example, theory change in science possesses some of these features but not others. The universal Darwinist who thinks of the notion of a Darwinian evolutionary process as a cluster concept can say that some non-biological processes (cultural change, scientific change, neural development, or whatever) are Darwinian evolutionary processes, on the grounds that they possess *enough* of the family traits of Darwinian evolutionary processes. However, scientific change and biological change do not have a shared essence; rather, they are related in much the same way that chess and football are related. What makes

Darwin's theory a universal acid is the fact that a number of other processes share some of the family traits of Darwinian evolutionary processes.

5. CONCLUSION

In this paper, I have not given any reasons for rejecting process essentialism. What I have tried to show, instead, is that (a) Dennett's process essentialism is incompatible with the suggestion he makes elsewhere that Darwinists should reject essentialism tout court; (b) universal Darwinists have not given any good empirical reasons for accepting process essentialism; and (c) there is no need for a universal Darwinist to be a process essentialist, because one can just as easily treat the concept of a Darwinian evolutionary process as a Wittgensteinian family resemblance concept.

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Darwinism, traditional linguistics and the new Palaeolithic Continuity Theory of language evolution

Mario Alinei

Professor Emeritus, University of Utrecht
The Netherlands
maalinei@tin.it

Abstract

As the author has shown in previous work, although linguistics as a science was born in Darwin's century, Darwinism's influence on it was superficial and produced the mystifying, but still current, view that language is a living organism, and language change an organic law. Language is, instead, a social artefact with an interface with nature, which is governed by the law of conservation and changes only exceptionally. Since language is innate—as claimed by Chomsky and now demonstrated by natural sciences—and *Homo* was thus born *loquens*, the evolution of language—and all world languages, including Indo-European (IE)—must be mapped onto the entire course of human cultural evolution, in the new framework provided by the Palaeolithic Continuity Theory (PCT).

1. INTRODUCTION

In this paper, I try to argue that the epistemological framework of traditional historical linguistics with regards to language evolution has always been and still is based on a misconception of Darwinism, and, therefore, needs a radical revision. The so called *organic linguistic change*, assumed by traditional linguistics as the governing law of language, itself considered as a biological *organism*, should be replaced by the view that language is a social artefact with an interface with nature, and that the only law of language, as of all other social artefacts, is *conservation*, whereas *change is the exception*, occurring only in certain periods and because of external influences. The conclusions of several sciences concerned with the origins and evolution of language also justify, in my opinion, the formulation of a new, interdisciplinary paradigm for the evolution of language and languages, which I have called the Palaeolithic Continuity Theory (PCT), and which elsewhere I have worked out in detail for the Indo-European (IE), Uralic and Altaic languages of Europe (Alinei, 1996–2000). The PCT, insofar as it provides us with a general evolutionary

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framework for all domains that find an expression in language—from grammatical structure to spiritual and material culture—can also contribute to the development of the EE.

2. THE INFLUENCE OF DARWINISM AND ITS PREDECESSORS ON THE EMERGING LINGUISTICS OF THE 19TH CENTURY

Linguistics as a new scientific discipline was born precisely in Darwin's century: the first comparative grammar of an IE linguistic group, the *Deutsche Grammatik* by Jakob Grimm (1785–1863), came out in 1819. August F. Pott (1802–1887), the founder of etymological research, published his *Etymologische Forschungen* in 1833–1836. The publication of the *Grammatik der romanischen Sprachen* by Friedrich Diez (1794–1876) was begun in 1836 and completed in 1843. Franz Bopp (1791–1867), one of the father founders of comparative-historical linguistics, began the publication of his *Vergleichende Grammatik* in 1833, and completed it in 1852, that is 7 years before 1859, when Charles Darwin (1809–1882) published his celebrated synthesis. The *Essai de Paléontologie Linguistique* by Adolphe Pictet (1799–1875), another milestone in historical linguistics and in the study of IE, was published it in 1859–1863. And the school of linguists called Neo-Grammarians (initiated by August Schleicher, 1821–1868), to whom linguistics owe the principle of the so called *organic linguistic change* and the *Lautgesetzen* ('laws of phonetic development'), were all active after Darwin, and thus made large use of Darwinian concepts and terms. In short, the 19th century was the period which saw the emergence of all sciences of the historical type, including historical linguistics.

Because of this synchronism, it is important to evaluate to which extent the new linguistic science was influenced by Darwinism and by its immediate precedents, a problem which only recently has begun to attract scholarly attention (e.g. Christy, 1983; Nerlich, 1990). And although at a first glance this influence seems important and deep, on a closer analysis it proves to be either superficial or based on a total misunderstanding of the epistemological nature of the evolution theory. Let us see the evidence for this claim.

2.1. The Cultural Context of the 19th Century

First of all, it is necessary to remember that the 19th century was *not* dominated, culturally, by the emergence of evolutionary theory, but, on the contrary, by a very conservative, theological view of nature, according to which the Bible was the basic source for knowledge, and thus also for science.

As is known (e.g. Daniel, 1962; Pinna, 1992), Pre-Darwinian scholarship saw the duration of the earth and of life, as well as the beginning of human history, as set down by the Bible. And the text of the Bible, in its authorized version published in England in 1701, included the results of Dr. John Lightfoot's and bishop James Ussher's earlier calculations, according to the latter of which the universe was created by God on Sunday the 23rd of October 4004 BC, beginning at sunset of the 22nd, Adam and Eve were driven out of Eden in the same year, on November 10, and Noah's ark saved living beings from the Flood on May 5, 1491 BC. Throughout the 19th century, and as late as the Victorian era—that is long after Darwin published his book—this was the current view about the origins of the universe. For the same reason, contemporary scholars reduced the entire human prehistory to the so-called *Four Monarchies*—Persian, Assyrian, Greek and Roman. And in the almost 6000 years between the present and the divine Creation in 4004 BC, nothing short of a catastrophic, supernatural event could explain the process of geological accumulation and change. The biblical Flood provided an exceptionally effective example of such a catastrophe. In short, before the four monarchies there was only impenetrable fog, and before the year 4000 BC was the supernatural.

And it was precisely the strength of this belief that caused, in the 19th century, a sharp division between contemporary scholars: On the one hand the majority, called Catastrophists, who interpreted the terrestrial documentation in conformity with the Book of Genesis, saw the Flood as an example of supernatural catastrophes, and the biological past of the earth as a succession of supernatural catastrophes, each followed by new acts of supernatural creation. And on the other a minority of scholars, called Uniformitarianists, who studied the earth and life in terms of natural phenomena and natural laws *operating in the present*, and affirmed the natural character of the evolution, and the uninterrupted continuity of species from their origins to the present, in spite of their transformations.

The conflict began in France, where catastrophism was represented by Georges Cuvier (1769–1832), natural historian, geologist and founder of the palaeontology of the vertebrates, and uniformitariamism, then called transformationism, by Jean Baptiste Lamarck (1744–1829), one of the main precursors of Darwin's evolutionism. In England, the main representatives of uniformitarianism was Sir Charles Lyell (1797–1875), who had a great influence on Darwin, and set out his theory in a classic study of the history of science, the title of which is a programme in itself: *Principles of Geology, being an attempt to explain the former changes of the earth's surface by reference to causes now in operation*, published in three volumes in London from 1830 to 1833.

2.2. The Reaction of Linguistics to the Polemic between Catastrophism and Uniformitarianism

Within this cultural framework, then, the precise question we must address is the following: How did the new historical linguistics react, first to the polemic between catastrophism and uniformitarianism, and then to Darwin's evolution theory? (Christy, 1983; Nerlich, 1990)

As I have already indicated, this reaction, on the surface, was very positive: most 19th-century linguists adhered to uniformitarianism, in the precise sense that they thought it coincided with the mysterious process of change they had discovered as a seemingly constant feature of language. The American scholar William D. Whitney (1827–1894), one of the most intelligent linguists of the 19th century, was one of the staunchest supporters of Lyell, whom he admired and cited many times and by whom he was profoundly influenced. The French scholar Michel Bréal (1832–1915), the founder of semantics as a linguistic discipline, expressed himself frequently in clearly uniformitarianist terms, although he did not refer to Lyell explicitly. The brilliant but superficial Max Müller (1823–1900) was perhaps the first to formulate the uniformitarianist principle in linguistics. As far as we know, only Heymann Steinthal (1823–1899) continued to favour explicitly catastrophism as an explanation of change.

Despite the appearance, however, this adhesion was superficial, and can be seen as a sort of compromise between the earlier dogmas of theology and the new scientific views of the evolutionists. For what really happened is this: (a) on the one hand the new linguists retained the pre-Darwinian idea that prehistory was an impenetrable mist—coinciding with the so called *antediluvian* period—and refused to take into consideration anything that had to do with it. (b) On the other, they misinterpreted completely the epistemological nature of the evolution theory, by applying it blindly to language, which they mistakenly assumed to be a biological, natural organism. And the combined effect of these two reactions was such as to put historical linguistics on a wrong track, which eventually led to a dead end, where it still finds itself at this very moment.

Let us see these two points in greater detail.

2.3. Influence of Catastrophism on Linguistics

The most evident confirmation that 19th-century linguistics, despite its superficial adhesion to uniformitarianism and Darwinism, refused to open their study to prehistory, retaining instead the pre-Darwinian idea that prehistory was an impenetrable fog, can be found in the censorious decision, taken in 1868 by the new, prestigious Société Linguistique de Paris, to introduce in its statute an article that prohibited the study of linguistic origins. The statute of the SLP did not admit "*aucune communication concernant [. . .] l'origine du langage*" (*Mémoires de la Société Linguistique de Paris*, 1868, 1: 111; cf. Nerlich, 1990: 39). And the date of 1868 proves that this decision was taken with the awareness of, and in opposition to, the new perspectives opened up by Darwinism.

Another piece of evidence of this refusal of prehistory can be found in the choice of the explanatory model for the origin of the main Euro-Asiatic language families, which were, for obvious reasons, the first to be studied by the new linguists: for all Proto-Languages reconstructed by the new linguists were seen to be of recent formation, emerging in Europe or Asia as late as in the Metal Ages, and submerging a sort of antediluvian, unknown and unknowable population. This is true not only of IE, who were seen—and still are both in the traditional model (Gimbutas, 1970, 1973, 1977, 1980) and in Colin Renfrew's (Renfrew, 1987)—as warlike superior elites, or as the inventors of farming, who obliterated the preceding populations of the continent; but it was true, until two decennia ago, also of Finno-Ugric people, who were seen as invaders in the Iron Age, coming from an unknown area and replacing unknown people; and of the Altaic people, who are still seen as even more recent, Medieval invaders, coming from nowhere and replacing earlier IE invaders, in the typical merry-go-round that characterizes the traditional ethnogenesis of Eurasia. In short, the languages of modern civilizations could not have anything to do with ancient prehistory.

A third aspect of this prehistoric reductionism, and of its flagrant contradiction with Darwinism, can be found in the already mentioned Linguistic Palaeontology, initiated with the homonym publication by Pictet in 1859–1863. Pictet used the term *paléontologie* to indicate a field of studies which he compared, significantly enough, to the studies "*du naturaliste qui étudie les regnes antédeluviens*". Consequently, it is obvious that he was still sailing in the waters of catastrophism. On the other hand, while the name Palaeontology evoked the *antediluvian* fossils of Palaeolithic, all of Pictet's linguistic analyses date the earliest layers of IE lexicon to the Copper, the Bronze and the Iron Age. Which proves, again, that IE palaeontology could not have anything to do with remote prehistory, but only with Metal Ages artefacts and institutions.

In short, in spite of a cosmetic operation meant to demonstrate a superficial adoption of uniformitarianism, there was a continued adherence to the ideology of pre-Darwinian catastrophism.

2.4. Additional Influences of Political Ideology

Of course, catastrophism was not the only influence that shaped the pseudo-historical scenarios painted for the origin of civilized languages by the first linguists. Many recent studies on history of archaeology, linguistics and ideology have shown that the foundation of scientific IE research in the 19th century was deeply influenced by the contemporary Arian, Pangermanic and colonialist ideology, as first expounded in Count Joseph-Arthur De Gobineau's, *Essai sur l'inégalité des races humaines* (1853–1855) and Houston Stewart Chamberlain's, *Die Grundlagen des XIX Jahrhunderts* (1899), with their emphasis on the racial superiority of the IE people and their inclination to war and conquest (e.g. Poliakov, 1974; Römer, 1985; Renfrew, 1987; Trigger, 1989, etc.).

We must not forget, in this context, that the very word Arian was one the basic terms of the emerging historical linguistics. And it might be useful, as a way of example, to read what the French Pictet writes about the Arian race in the opening lines of his already cited book, the title of which was, significantly, *Les origines des Indo-européennes ou les Aryas primitif. Essai de paléontologie linguistique:*

> une race destinée par la Providence [. . .] à dominer un jour sur le globe entier [. . .] Privilégée entre toutes les autres par la beauté du sang, et par les dons de l'intelligence . . . cette race féconde travaillait [. . .] à se créer, comme puissant moyen de développement, une langue admirable par sa richesse, sa vigueur, son harmonie et la perfection de ses formes. (Pictet, 1859–1863: 7)

This kind of ideology made a radical distinction between the IE people and all the savage populations of the world, which were destined to remain such. The autochthonous populations of prehistoric Europe—wholly similar to the savages of the other continents—could not have had anything to do with historic and modern Europeans, and consequently the prehistory of the IE people belonged to a kind of obscure and impenetrable limbo, a sort of scientific substitute for the dogma of creation.

It is this mixture of residual catastrophism and pre-racist ideology that seems to me to characterize much of the linguistic work of the 19th century, and which the later generations of scholars came to accept by sheer inertia.

2.5. Misinterpretations of Darwinism by the Emerging Science of Linguistics

But the greatest, and at the same most pernicious, influence that Darwinism exercised on the emerging science of linguistics, and which deserves our closest attention, concerns the basic tenet of the evolution theory, namely the principle of gradual and constant evolution of nature, following specific laws. For this principle was applied mechanically to language, on the basis of a total mystification of the epistemological nature of Darwinism, with the consequent assumption that also language was a living organism.

This is, in my opinion, the fatal mistake that 19th-century linguistics made, and which has been inherited by linguistics until now: the *reification* of languages into living organisms, each of which has a birth, a life and a death, and it evolves as all natural organisms, following laws that are similar to laws of nature. Laws that have been called—precisely by 19th-century linguists—*Lautgesetzen* or *phonetic laws*, and which have been assumed as a given of nature, escaping knowledge, precisely as biological change. This is why the most typical principle of the new historical linguistics was and is the so called *linguistic organic change*, and this is also why most 19th-century linguists considered themselves as supporter of the principle of uniformitarianism, since the idea that language evolved following natural laws looked exactly like what the uniformitarianists had discovered about nature.

It is, therefore, apparent that the influence on Darwinism on the emerging linguistic science was characterized by two basic misinterpretations of it: (a) On the one hand, the adhesion to the principle of uniformitarianism by linguists was based on the misconception of language as a living organism, whose so called organic change was consequently placed outside the scope of knowledge and critical study. (b) On the other, while all other historical sciences, geology, biology, archaeology, palaeontology and anthropology, freed from the concept of catastrophism, transformed the antediluvian period into the very object of their study, thus opening its abysmal depths to observation and research, linguistics still regarded prehistory as a period of absolute darkness, and thus totally irrelevant. (c) As a consequence, the organic change of language, unlike geological and biological change, was situated in a chronological horizon, which remained in essence still Biblical and postdiluvian. And in this framework the organic clock by which language change was being measured had also necessarily to be extremely rapid, to make things fit.

In short, the whole scenario of the Proto- IE language still unified landing on Europe in the Copper Age with its blitz-invasion, the fantastic rapidity of its change into the different IE languages, and the simultaneous extermination of the savage pre-IE s, all come out of this context, with the addition of the pre-racist, colonialist ideology prevailing in the 19th century.

Traditional linguistics thus continued, without wanting or knowing it, the line of pre-scientific *post-diluvian* studies. The enormous, almost infinite chronological span revealed by scientific research, which demolished the Biblical myth of the creation and gave rise to innumerable achievements in the field of geology, biology, genetics, archaeology and all the sciences studying prehistory, has never been really laid open for historical and comparative linguistics. The traditional catastrophistic view arrested the development of historical linguistics at positions typical of the pre-scientific stage of the 19th century, positions which became as dry branches, incapable of rejuvenation and destined simply to fall off.

3. REVISITING TRADITIONAL VIEWS ABOUT LANGUAGE AND LANGUAGE CHANGE

In the light of this historical reconstruction of the period in which linguistics as a science emerged, it becomes then evident that two are the most important revisions that historical linguistics must undergo: (1) the view that language is an organism, and thus changes according to a sort of natural law; and (2) the view that the horizon of language development must be restricted to recent prehistory. Let us review the new conclusions that have been reached about these two points.

3.1. A New View of Language Change

As far as language change is concerned, I will summarize my own views about it, based on relevant literature (Alinei, 1996–2000, 2004a).

First of all, after one and a half century of intense research on the nature of language, it needs no demonstration that language and languages have nothing to do with natural organisms and natural laws. Language as such, and consequently each historical language has, of course, a fundamental *interface* with nature, but it is not a natural organism. Language is, quite evidently, a social artefact, not different, in essence, from any other social artefact, such as money, games, laws, and even houses, tools, clothes, and the like; and, of course, all social artefacts have a fundamental interface with nature. We will see shortly how relevant its interface with nature is to understand the connection between language and prehistoric cultural evolution, but first let us address the question of the nature of language change.

Language does change, of course, but it does in the same way as other social artefacts change. Language change is not different from the changes we observe in money, laws and other institutions, houses and tools. More specifically, *language changes in two distinct ways: lexically and grammatically*. Neither has anything to do with organic change. Lexical change is culture-dependent, and it occurs without changing its grammar. *It is the only change we always experience during our life*. Grammatical change is history-dependent, in the sense that it occurs only in times of social upheaval (the ultimate causes of which can be multiple: climatic, economic, social, political, as well as technological, cognitive, cultural, etc.), *as a form of hybridization*, and thus as a *psycholinguistic adjustment to a differing linguistic model*.

No individual, in normal conditions (i.e. in conditions of social stability), experiences grammatical change in the course of his life. In normal conditions, on the contrary, each of us experiences that her/his language is the same of her/his grandparent, and is the same spoken by her/his grandchildren. Each of us experiences, in short, the continuity and the conservation of language through five generations: two before and two after ours. The only *law* inherent to language is *conservation*: a law comparable, to a certain extent, to Newton's law of inertia. But the cause of this impossibility to experience linguistic change in the course of one's life must not be attributed to the *slowness* of grammatical change,[1] but simply to the absence of changing factors in what I have defined as a socially normal context.

In periods of social upheaval—as for example the writer himself experienced in Italy at the end of Fascism, with the beginning of democracy and the resulting formidable social adjustments—grammatical change *can* be observed. In that specific context it took the form of low-class or dialect features, until then refused by the previous norm, suddenly becoming part of the new norm. To understand how this works, of course, one has to recall the nature of stratified societies, and their inevitable sociolinguistic reflexes, as illustrated, for example, by Labov's seminal work (e.g. Labov, 1965a, 1965b, 1966).

Contrasting *strong encoded languages* to *oral languages*—as suggested by one of my critics—is then certainly necessary: in the fist place because of the intrinsic difference between spoken and written language, and the greater susceptibility to change of the former than of the latter; in the second because of the nature of stratified societies, which brings the standard oral norm in close contact with that of spoken urban and regional substandards. And the example suggested by my critic—the disappearance of *ne* in the French negation *ne*... pas (where *pas* 'step'—from Latin *passum*—was originally an emphatic form of the normal pre-verbal negation)—is indeed fitting, being typical of spoken French, and not of its strong encoded version.

To complete the picture, however, we must introduce yet another distinction, for here we are dealing, in fact, with *two* grammatical changes: (a) the *oral* grammatical change bringing about the disappearance of *ne*, which has probably taken place in the *oïl* dialect area, centuries ago (cf. all '*ne*...*pas*' maps of Gillieron's *Atlas Linguistique de la France* (1902–1908), which provide us with a detailed picture of the situation in 19th century France), for reasons which I will explain shortly; and (b) the appearance of the same feature in the *spoken* language of the educated French person, which is certainly a more recent phenomenon, and ultimately depends on the swinging of the social pendulum in French society in the last 50 years.

As to the causes of the first oral change, which underlies the second, what should attract our attention as linguists is its ultimate outcome: for what it actually did was to turn the *Latin* type of a *pre-verbal* negation *non est* into a non-Latin *post-verbal* negation *c'est pas*, comparable to the Germanic standard (*is not*, *ist nicht*, *is niet*, *är inte*, etc.), to the Welsh oral norm and to the norm of most French dialects and northern Italian dialects: a geographical distribution which represents a classic case of *compact area*. The change, then, can easily be seen as a form of adjustment (i.e. hybridization) by speakers of a Latin type of language to a non-Latin type of language, ultimately under

[1] As assumed, for example, by an anonymous reader of my article.

the strong influence of a non-Latin social group. And this irrespectively of whether this social group was an intrusive elite acting as a *superstratum* on the original language, or an upcoming autochthonous lower class acting on the elite as a *substratum*, or a neighbouring peer-group acting as an *adstratum*. Needless to say, such a change does not contradict, but confirms the thesis of the dependency of major grammatical changes on external causes.

As to the *tempo* of grammatical change, as I have tried to argue elsewhere (Alinei, 1996–2000), everything points to its rapidity, in fact instantaneity, once the social conditions for it have been met. As instantaneous, for example, as is the adjustment to one's own language that any non-English speaker will make when he speaks English, or to one's own substandard or regional standard that any language speaker will make in pronouncing a *new* word.[2] As we know, both adjustments result in an *accent*, which—incidentally—is one of the typical forms of *potential* linguistic change we can observe at will around us. The processes which do involve a time dimension in grammatical change are only its preparation (the social context), as well as its subsequent diffusion and generalization.

In short, grammatical change should not be seen as altering the continuous and steady line of language conservation, resulting from the above-mentioned inertia principle of language stability, but as a dramatic and rapid episode, connected ultimately with a social *earthquake* (the causes of which, as I have said, can be multiple), which results in a greater or smaller measure of psycholinguistic remodelling, and is eventually followed by the resumption of the normal stability pattern. A view of language evolution which seems to me perfectly in line with Gould's *punctuated equilibrium* of biological evolution.

3.2. New Scenario's of Language Continuity

In the light of this new view of linguistic change, the evolution of language and languages ought to be placed in a direct relationship with the human prehistoric evolution, and studied with the proper interdisciplinary tools (Alinei, 1996–2000).

The guiding, theoretical principle in this study (for a detailed illustration of which I refer the reader to my main work (idem) ought to be the so called uniformitarianist or actualist principle: *the present is the key to the past*. As is known, this principle—by which the general laws operating in the past are basically the same that operate now—is considered as the foundation of all natural sciences of the *historical* type, such as geology, biology, palaeontology, anthropology and archaeology. However, while for these sciences, after

[2] As, for example, the many regional variations in the phonetic and phonemic shape of the It. word /televizj'one/, which were realized immediately upon the introduction of the new word.

the rejection of catastrophism, the adoption of this principle opened the door to the study of prehistoric past and marked the beginning of their scientific phase, linguistics—as we have seen—never really rejected catastrophism, and, therefore, still considers the present as totally irrelevant for the study of the prehistoric past, and prehistory as a totally unknown and unknowable universe. The PCT, on the contrary, starting from rigorously uniformitarian premises and discarding all assumptions of catastrophic events such as gigantic language replacements/extinctions on a continental scale, proposes, as a general working hypothesis, the principle of the strict correspondence between the areal distribution of historically attested languages and the original spread of *Homo loquens*.

Support for this claim is easy to find.

Concerning the languages of the Australian aborigines, for example, it is now accepted without a shade of doubt that they are a continuation of those of the earliest inhabitants of the continent, who populated the island 40,000 years ago.

Also with regards to the indigenous languages of the Americas no one doubts that they represent a continuation of the languages of the earliest immigrants, who came to the New World, most likely through the Bering Strait, at a controversial date, but probably not before 23,000 BC.

In the last 30 years, there has also been an important breakthrough in the history of one European population: this is the so called Uralic Continuity Theory (in Finnish: *uralilainen jatkuvuusteoria*), developed in the 1970s by archaeologists and linguists specialized in the Uralic area of Europe, that is the area of Finno-Ugric and Samoyed languages. While the origins of Uralic people was previously seen in a very recent, Iron-Age invasion, following the traditional catastrophist model, the now current theory claims an uninterrupted continuity of Uralic populations and languages from Palaeolithic: Uralic people would belong to the heirs of *Homo sapiens sapiens* coming from Africa, they would have occupied mid-eastern Europe in Palaeolithic glacial times, and during the deglaciation of Northern Europe, in Mesolithic, would have followed the retreating icecap, eventually settling in their present territories (Meinander, 1973; Nuñez, 1987, 1989, 1995, 1997, 1998).

These conclusions, concerning language phyla of both the New and the Old World, point then to the basic continuity of present languages from a Palaeolithic *Homo loquens*, and thus to a much greater chronological depth than traditionally thought for the evolution of language and languages.

We must now see if we are justified in formulating our thesis in more general terms, including IE languages (which have always been considered as the testing ground of competing theories), and if we can find support for it in the conclusions of other sciences and disciplines that deal with language origins and with prehistoric evolution.

4. AN INTERDISCIPLINARY SURVEY OF CONVERGING CONCLUSIONS ON A PRE-HUMAN ORIGIN OF LANGUAGE AND A MUCH LONGER EVOLUTION OF LANGUAGES

In recent times, at least five different sciences and disciplines have addressed, from different vantage points and with different approaches, the problem of the origin and evolution of language and languages, and that of demic and cultural continuity throughout prehistory. These five sciences are: (a) general linguistics, (b) palaeo-anthropology, (c) cognitive science, (d) genetics and (e) archaeology.

Of these five sciences, the first three converge towards the claim that language has a pre-human origin—which implies an evolution of languages going from the birth of the genus *Homo* to modern times—i.e. in the order of millions of years. I have called this scenario the *Long* PCT (Alinei, 1996–2000). The last two sciences, instead, have reached conclusions about genetic and/or cultural continuity the implications of which do not go beyond Upper or Middle Palaeolithic. They are, nevertheless, relevant for this discussion. I have called this scenario the *Short* PCT. Although, for reasons that will become clear in what follows, I favour the Long PCT, in my work I have shown that also the time depth provided by the Short PCT is such as to require a total revision of our views on the evolution of language and languages (idem).

We will now review these conclusions and see whether, and to which extent, they support our claim.

4.1. General Linguistics

In general linguistics, the central idea of Noam Chomsky's revolutionary theory on the psychological and formal foundations of language is centred upon the claim that *language is innate*. In evolutionary terms, however, the claim that a human faculty is innate implies that its origin must be placed *earlier than the emerging of Homo*: and no linguist or interested scholar, until recently, would have taken such a hypothesis seriously. On the contrary: under the influence of traditional (and still quite current) assumptions about a (very) recent origin of language and languages, the general tendency was to consider Chomsky's innatism incompatible with an evolutionary, Darwinian point of view: "*Chomsky and some of his fiercest opponents agree on one thing: that uniquely human language instinct seems to be incompatible with the modern Darwinian theory of evolution*" (Pinker, 1994: 333; cf. Agrawal and Kusumgar, 1996; Gontier, this volume).

A major breakthrough, however, independently made by scholars specialized in two entirely different sciences, is at present forcing general linguistics to reconcile Chomsky's innatism with a Darwinian framework, and thus to address the problem of the evolution of language and languages in an entirely new way. My answer to this challenge is the Long PCT.

4.2. Palaeoanthropology

Among natural sciences, palaeoanthopology has probably contributed the most to the breakthrough I have just mentioned. For the last 20 years of discoveries in the field have brought several scholars, among which one of the world leading specialists, Ph. V. Tobias, to conclude that the question now is no longer whether *Homo habilis* spoke (which is now considered as ascertained), but whether the capacity for language was already optionally present in some *Australopithecus*, to become obligatory in *Homo*, as one of his unique traits. As Tobias himself writes:

> Several lines of evidence suggest that the rudiments of speech centers and of speaking were present already before the last common ancestral hominid population spawned *Homo* and the robust australopithecines [. . .] Both sets of shoots would then have inherited the propensity for spoken language. The function would probably have been *facultative* in *A. robustus* and *A. boisei*, but *obligate* in *Homo*. (Tobias, 1996: 94, author's emphasis).

This conclusion, in my opinion, represents a firm empirical basis for the Long PCT, i.e. for the claim of a pre-human origin of language and for the consequent necessity to view the evolution of language and languages in a new way.

4.3. Cognitive Sciences

On the basis of independent evidence, a similar conclusion has been reached also in the field of cognitive sciences, by Steven Pinker, in his remarkable book on *language instinct*, inspired by Chomsky's theory of language (Pinker, 1994): "*a form of language could first have emerged [. . .] after the branch leading to humans split off from the one leading to chimpanzees. The result would be languageless chimps and approximately five to seven million years in which language could have gradually evolved*" (Pinker, 1994: 345). Needless to say, this longer evolution for the *origin* of language automatically implies a much longer chronology for the *following evolution* of language and languages and thus something similar to the Long PCT.

Recently, Chomsky himself has made an important contribution to the debate on the biological foundations of language innatism by distinguishing between a Faculty of Language in a Broad sense (FLB), shared with higher animals, and an FLN (FL in a Narrow sense), uniquely human (Hauser et al., 2002). However we interpret it, this proposal too implies the opening to research of the immense space from the origins of *Homo* to the present day, and thus a conception of language and languages evolution identical, in essence, to the Long PCT.

4.4. Genetics

The school founded and led by Luca Cavalli Sforza has made important discoveries about the relationship between genetics and linguistics, which could also be integrated in the view of a much earlier evolution of languages than traditionally thought, though without reaching *Homo*, but only *Homo sapiens sapiens*, and thus within the limits of the Short PCT. These conclusions are: (a) the areal distribution of different genetic markers largely corresponds to that of the world languages (Menozzi et al., 1978; Cavalli Sforza et al., 1988, 1994); (b) language differentiation must have proceeded step by step with the dispersal of Modern Humans (who, as is known, for most geneticists coincide with *Homo sapiens sapiens*) (idem).

Unfortunately, these conclusions have not been elaborated in any significant way by their authors, not even within the framework of something similar to the Short PCT. In fact, for the specific problem of the origins of IE languages Cavalli Sforza has first attempted to adjust his data to the traditional model of the warlike invasion theory, claiming that the two data converged, and later fully supported Renfrew's model (Ammerman and Cavalli Sforza, 1984), without realizing—apparently—that also the latter model, with its *catastrophic* scenario for both European and Asiatic people, clashes with his own claim of a close correspondence between the areal distribution of genetic markers and that of world linguistic phyla.

Nevertheless, even Cavalli Sforza has recently had to surrender to the latest outcome of genetic research, i.e. that 80% of the genetic stock of Europeans goes back to Palaeolithic (e.g. Sykes, 2001: 240 ff). As Bryan Sykes has recently commented: "*The Neolithic farmers ha[ve] certainly been important; but they ha[ve] only contributed about one fifth of our genes. It [is] the hunters of the Palaeolithic that ha[ve]created the main body of modern European gene pool*" (Sykes, 2001: 242).

This conclusion represents, in my opinion, a firm basis for the Short PCT.

4.5. Archaeology

In the last three decades, archaeological research has made quite a few revolutionary advances, among which the most well-known is the much higher chronologies of European prehistory, obtained by radiocarbon and other innovative dating techniques. As far as Europe is concerned, the conclusion that interests us the most are:

(a) There is absolutely no trace of a gigantic warlike invasion, such as to have caused a linguistic substitution on continental scale, as envisaged by the traditional IE theory.
(b) All Neolithic cultures of Europe are either a direct continuation of Mesolithic ones, or have been created by Mesolithic groups after their Neolithization by intrusive farmers from the Middle East.
(c) There is every possible evidence for demic and cultural continuity, from Upper Palaeolithic to the Metal Ages. Continuity is now universally considered the basic pattern of European prehistory. Even James Mallory, probably the last archaeologist who defends the IE invasion theory, has had to concede: "*the archaeologists' easiest pursuit [is] the demonstration of relative continuity and absence of intrusion*" (Mallory, 1989: 81).

All of this, again, represents a firm basis for the Short PCT.

5. THE NEW SYNTHESIS: THE PCT

On the basis of these converging conclusions, a general PCT on language origin and evolution, worked out in detail as far as its *Short* version is concerned, and in particular with regards to the origins of the IE people, has been proposed (Alinei, 1996–2000, 1998a, 2000a, 2001a, 2002, 2003a, 2003b, 2004b, 2004c; for other supporters see below), the main points of which are described as follows.

5.1. Antiquity and Stability of Language and Languages

Homo was born *loquens*. Language and languages appear with *Homo* himself. This is, in essence, the Long PCT. But even if we assumed—with some scholars—that *Homo sapiens sapiens* started to speak a totally new kind of language, i.e. with a total *tabula rasa* with regard to the now ascertained previous language evolution, we would still have to map the evolution of language and languages onto the chronology of the Short PCT: the record of all world languages ought to be classified following prehistoric and historical periodization categories (Palaeo-, Meso-, Neolithic, Metal Ages, historical periods), instead of being compressed into a few millennia, as traditionally done, and as even Renfrew's Neolithic theory would oblige us to do. While traditional linguistics, by reifying language and seeing it as a natural organism, had made *change* into a sort of biological, organic law of language development, the extraordinary tempo of it would fit the short chronologies of the recent invasion or of the earlier Neolithization, the above illustrated view that conservation is the law of language and languages, and *change the exception*, caused by major external factors, makes it possible to fit the new, much longer chronologies of language origins and language development with the major ecological, socio-economic and cultural stages that have shaped each area of the globe (Alinei, 1996–2000).

5.2. Antiquity of the Grammatical Differentiation between Languages: The Hypothesis of an Areal and Cognitive Correlation between Lithic Technologies and Language Types

On the basis of the theory formulated by Jean Piaget (1952, 1954, 1955) and by his precursor Lev S. Vygotsky (1962/1934), according to which *action, and not perception, precedes intelligence*, and on the conclusions on developmental cognitive evolution of such authors as Leroi-Gourhan (1964), Parker and Gibson (1979), Holloway (1981, 1983), Holloway and De La Coste-Lareymondie (1982), Leakey and Lewin (1992), Gibson and Ingold (1993), Gibson (1996), I have advanced—within the scenario of the Long PCT—the hypothesis that the differentiation between the three main, and geographically differentiated, world types of grammatical structure—i.e. (a) *Isolating*, (b) *Inflecting/Fusional and* (c) *Agglutinative*—might be correlated to the development of the three major, and geographically differentiated, world types of lithic technology—i.e. (a′) *Choppers*, (b′) *Bifacials* (*Handaxes*) and (c′) so called *Mode1* (later *Leptolithic*) tools. Arguments for this claim are: (1) the close correspondence between *the well-known, complementary world areal distribution of these three types of lithic tools* (e.g. Schick, 1994) *and the less known complementary world areal distribution of the three main types of grammatical structure*; (2) the cognitive and operational parallelism between the three types of lithic tools and the three types of lexical structure (Alinei, 1996, 1996–2000, 1997e; Nuñez, 2002).

For other grammatical changes possibly connected with major technological developments of *later* Palaeolithic, I refer the reader to my main work (Alinei, 1996–2000).

A different kind of grammatical differentiation, compatible also with the Short PCT, can be seen in the *grammatical words shared by the languages of a single language phylum*, such as personal pronouns, WH-words, prepositions and the like: for these surely reflect the awakening and developing of human conscience and reality-structuring capacities of speakers of *already separated and independent language phyla*. As a consequence, considerations of the similarities in the lexicon of the grammatical structure shown by some language phyla (e.g. IE, Uralic, Altaic), as well as of the differences between most of the others, point to an oligogenetic or polygenetic model of language origins. These considerations are for example entirely missing in Ruhlen's monogenetic reconstruction (Ruhlen, 1994).

5.3. Antiquity and Periodization of the Lexicon of Natural Languages

An important corollary of this new conception and new chronology of language origins and development is that the emerging and formation of the lexicon of all world language phyla and their groups, including IE, should be *periodized* along the entire course of human evolution (following the Long PCT) or from Middle Palaeolithic on (following the Short PCT), instead of being compressed in the recent prehistory, as typical of the traditional theory as well as Renfrew's. The linguistic illustration of this principle fills many of the 2000 pages of my two volumes (Alinei, 1996–2000), as well as many of my articles (Alinei, 1991, 1992, 1997a, 1997b, 1997c, 1997d, 1998b, 1998c, 2000b, 2001b, 2001c, 2001d) and represents the first detailed linguistic analysis of the IE record in the light of the new chronologies and scenario imposed by scientific advance. We have already seen—in 4.2—the example of the grammatical words, certainly belonging to the earliest layer of a language (super)phylum. Here are some more examples of the *lexical periodization* applied to IE, and compatible with both the Long and the Short PCT:

(1) In general terms, the Proto-lexicon, i.e. the lexicon common to all languages of a language phylum, as for example IE, forms by definition its earliest layer. As such it ought to be placed in the depth of Palaeolithic.

(2) If IE words for 'dying' (coming from Proto- IE ***-mer)** belong to the Proto- IE lexicon, while for 'burying' there are different words in most IE languages, this must be seen as evidence that by the time ritual burying began, in Upper Palaeolithic, IE groups (Celtic, Germanic, Italid, Slavic, Greek, etc.) were already differentiated. Similarly, if the name of several wild animals, among which that of the bear (Proto- IE ****rkPo-s***), belong to the Proto-IE lexicon, this means that these animals belonged to the cognitive and cultural world of IE pre-religious Palaeolithic hunters. Conversely, the so called *noa* names of the bear (i.e. replacing the tabooed real one) in the Celtic, Germanic, Baltic and Slavic languages, all different from one another, can only indicate that by the time religious concern for hunted animals connected with totemism emerged in Upper Palaeolithic (along with the earliest attestations of bear cult), IE languages were already differentiated (Alinei, 1996–2000, 2002, 2003b).

(3) Also words for typical Mesolithic inventions, such bow, tar, fishing tools, carpentry and many others, are different in each IE group, proving that by Mesolithic time IE languages were already differentiated (ibidem).

(4) The sharp, and now at last admitted even by traditionalists (Villar, 1996), differentiation of Neolithic farming terminology in the different IE languages, while absolutely unexplainable in the context of Renfrew's theory,

provides yet another fundamental proof that the differentiation of IE languages goes back to remote prehistory.

5.4. Archaeological Frontiers Coincide with Linguistic Frontiers

The existence and the stability or mobility of frontiers between prehistoric cultures, in the different periods of prehistory, has been ascertained by archaeology, and is clearly illustrated by charts archaeological chrono-stratigraphical charts (initiated, as is known, by Gordon Childe (Childe, 1925/1957; Burkitt-Childe, 1932). These charts can be of significant help to historical linguists because:

(a) Depending on their chronological depth, importance and stability, the cultural frontiers shown by them can be seen as corresponding to linguistic-family frontiers, to linguistic-group frontiers, or to dialect frontiers.
(b) The various geographical sub-areas indicated by the columns of an archaeological chart are not chosen subjectively, but their delimitation is self-generated, i.e. governed by the very specific and exclusive sequence of cultural development, which shapes—as it were—each sub-area, identifying and distinguishing it from the others.
(c) Each cultural sequence, corresponding to a given geographical sub-area, has thus a very distinct and strong cultural *identity*, which could easily be connected, depending on the period and the area involved, with a language family, a language group, or a dialect group. In southern Europe, for example, the Neolithic Cardial Ware can be seen as corresponding to an already differentiated Italid group, and each of its later sub-areas can be interpreted as representing a kind of *dialect* differentiation from the same common *language*. The same can be said for the LBK in Germany, and for similar large cultural units in other areas.
(d) As far as Europe is concerned, the picture revealed by these charts, already evident as soon as the archaeological record permits adequate geographical mapping of cultures (i.e. in the late Palaeolithic and Mesolithic), is one of the formation of large *ethnolinguistic and cultural orbits*. This picture continues also in the early Neolithic, until, beginning in the course of Neolithic, and steadily increasing in the Metal Ages, a fragmentation of each original *orbit* takes place. Some periods of frontier shifting and transitional discontinuity, which are caused by the transitory expansion of elite groups in the late Metal Ages, usually come to an end in subsequent developments, with the reappearing of the previous frontiers.

All of this seems to correspond quite closely with what we should expect if one or more populations speaking one and the same language—such as the Proto-IE or the Proto-Uralic people—had first spread to Europe from

Africa, and then had broken up into different groups (*cultural orbits*), as a result of their exposure first to different ecological niches, different social networks and different neighbours, then to waves of intrusive immigrants introducing agriculture and stock-raising in Neolithic, and later, in the Metal Ages, when stratified societies develop, to waves of invading elites of akin or distant groups, speaking cognate or foreign languages.

As examples (for a detailed illustration see Alinei, 1996–2000, 2001b, 2002, 2003b, 2004b, 2004c) I will briefly mention here:

(1) The linguistic-phylum frontier between Uralic and IE in the Baltic area coincides with the extremely stable Latvian archaeological frontier separating, from Mesolithic to Chalcolithic, the Kunda, Narva, Pit-and-Comb Ware cultures of the Uralic-speaking area in the North, from the Nemunas 1, Nemunas 2, Globular Amphora, Corded Ware/Boat Axes and Bay Coast cultures of the IE, Baltic-speaking area in the South.
(2) The language frontier between French and German in Alsace coincides with the stable archaeological frontier separating the Neolithic and Chalcolithic cultures of Chassey, Michelsberg, SOM, Vienne-Charente, etc., of the Celtic (now French-speaking) area, from those of the LBK, SBK, Hinkelstein, Grossgartach, Rössen cultures, etc., of the now German-speaking area.
(3) The complex of language and dialect frontiers in the Western Alps, respectively, between German and Neo-Latin in Switzerland, between Franco-Provençal and *oïl* in Switzerland, between Franco-Provençal and Occitan in France and Italy, and Gallo-Italic in Italy, coincide with the archaeological frontiers separating, in the different Alpine areas, the Cardial/Impresso-derived cultures of the Italid-speaking area from the LBK-derived cultures in Germanic Switzerland. More precisely: on the one hand Cortaillod corresponds closely to the Franco-Provençal dialects, Chassey to Occitan, Lagozza to Gallo-Italic dialects; on the other Pfyn and Rössen corresponds with the Alemannic, Swiss-German dialect area. More over, on the Ligurian coast and the Piedmont Alps, the frontier between Occitan and Gallo-Italic dialects corresponds to the prehistoric frontier between Chassey and the VBQ culture of the Po Valley.
(4) On the steppes of Eastern Europe, a conspicuous and well-known Neolithic-Chalcolithic frontier separates the farming cultures of Bug-Dnestr, Tripolye AI, Tripolye AII, Gorodsk-Usatovo, Corded Ware and Globular Amphora in Ukraine, from the pastoral, horse-raising and horse-riding cultures of Sursk-Dnepr, Dnepr-Donec, Seredny Stog/Chvalynsk, Yamnaya (*kurgan*!) and Catacombs, in the Pontic steppes: this is the frontier that moved Marija Gimbutas to envisage the epochal clash between the peaceful autochthonous non-IE farmers of her *Old Europe*,

and the warlike intrusive IE who submerged them. In the light of the PCT and of the available linguistic evidence, instead, this frontier corresponds to an earlier linguistic phylum frontier between an already separated and flourishing eastern Slavic population of farmers to the West, and warlike Turkic pastoral nomadic groups to the East, which would be responsible, among other things, of the two innovations of horse raising and horse-riding.

Linguistically, the new interpretation has the advantage of explaining (a) the antiquity and the quantity of Turkic loanwords *precisely for horse terminology* in both branches of Samoyed, in the Ugric languages, as well as in Slavic languages, and (b), more generally, the quantity of Turkic agro-pastoral terms in South-Eastern European languages, including Hungarian, which would have been brought into its present area precisely by the Turkic *kurgan* culture (Alinei, 2003a).

5.5. The Main Lines of the PCT Historical Reconstruction for IE

As far as Europe and IE are concerned, the fundamental lines of the PCT historical reconstruction are:

(1) The *arrival* of IE people in Europe and Asia must be seen as one of the major episodes of the arrival of *Homo* (*sapiens sapiens?*) in Europe and Asia from Africa, and not as an event of recent prehistory.
(2) The differentiation process of IE languages from the Proto-IE common language, reconstructed by comparative linguistics, as well as that of their already separated branches (Proto-Celtic, Proto-Germanic, Proto-Italic, Proto-Balto-Slavic, Proto-Greek, etc.) into their presently *substandard*, *dialect* varieties, must have taken an extremely long time, and they must have been associated first with the varying episodes of the original migration from Africa, and then—with an increasingly faster tempo as social stratification and colonial wars began—with the varying cultural, social and political stages the new fragmented groups went through in the different settlement areas.

For example:

(a) The *mysterious arrival* of the Celts in Western Europe, obligatory in the traditional theory as well as in Renfrew's—is replaced by the scenario of an early differentiation of Celts, as the westernmost IE group in Europe. Western Europe must of course have always been Celtic, and the recent prehistory of Western Europe—from the Megalithic culture through the Beaker Bell to the colonialist La Tène—must have all been Celtic. Consequently, the duration of the colonial expansion of the Celts was much longer than thought, and its direction was from West to East and not vice versa.

(b) The extremely successful (and sedentary) Mesolithic fishing cultures of Northern Europe must be attributed to already differentiated Celtic, Germanic and Baltic people, besides to Uralic people.

(c) The continental Germanic area must have extended, before the deglaciation, from the Alps to the icecap, including what are now the Frisian islands and part of the British islands. After the deglaciation, in Mesolithic, it expanded to Scandinavia (where its earlier, Mesolithic stage is still best preserved), and its first Neolithic appearance was the LBK. While the conspicuous fragmentation of the LBK, caused by the complexity of the recent prehistory of the area, is reflected by the rich dialect picture of Germany and of the contiguous Germanic-speaking countries, the much simpler prehistory, and the completely different geographic context of Scandinavia, made it possible for much of the language original characters to be preserved.

(d) What is now called the Romance area—closely corresponding to the area of the Epigravettian Palaeolithic culture, of Mesolithic cultures such as Castelnovian and Sauveterrian, and of the Impresso/Cardial culture of Neolithic—instead of representing solely the remnant of Roman imperialism, must now be seen as mainly an original Italid (or Italoid, or Ibero-Dalmatic) linguistic area, in which several proto-languages akin to Latin, besides Latin and the other Italic languages, were spoken (besides Alinei, 1996–2000, see also 1991, 1997c, 1997d, 1998b, 1998c, 2000b, 2001b, 2001c), and for the speakers of which the Latin of Rome must have been an (easy to learn) superstrate. Rumanian appears to be an intrusive language, introduced in Neolithic times into the Slavic area by Impresso/Cardial farmers coming from Dalmatia (Hamangia culture).

(e) The totally absurd thesis of the so called *late arrival* of the Slavs in Europe must be replaced by the scenario of Slavic continuity from Palaeolithic, and the demographic growth and geographic expansion of the Slavs can be explained, much more realistically, by the extraordinary success, continuity and stability of the Neolithic cultures of South-Eastern Europe (the only ones in Europe that caused the formation of *tells*) (Alinei, 1996–2000, 2004c).

5.6. A Short History of the PCT

In the 1990s, three archaeologists and three linguists, all independently from one another, presented a new theory of IE origins, which is similar to the Uralic continuity, in that it claims uninterrupted continuity from Palaeolithic also for IE people and languages. The three archaeologists and prehistorians are the American Homer L. Thomas (Thomas, 1991), the Belgian Marcel Otte (Otte, 1994, 1995), one of the world major specialists on Middle and Upper Palaeolithic, and the German Alexander Häusler, a specialist in the prehistory of Central Europe (Häusler, 1998, 2003). The linguists are, besides the writer, Gabriele Costa (Costa, 1998, 2000, 2001, 2002, 2003), and Cicero Poghirc (Poghirc, 1992). Two more linguists are now working on the same line (Ballester, 1999, 2000, 2001, 2004; Cavazza, 2001), and more have expressed their general assent (Contini, 2000; Benozzo, 2002; Simoni Aurembou, 2002; Le Du, 2003). The PCT can also list illustrious predecessors among IE specialists, such as the German H. Kühn (1934), the Bulgarian Vladimir I. Georgiev (1966) and the Italian Marcello Durante (1977). Recently, an international group of scholars have opened a website (www.continuitas.com) devoted to the PCT.

6. CONCLUSION

It should be clear by now that though the PCT has been worked out in detail only for IE, Uralic and Altaic languages, it aims at becoming the *general paradigm for the origin and the evolution of all of the world language phyla, and thus for language as such*. If then the PCT can be regarded as successful, not only in its results but also in its methods of seeking evidence in archaeology, (palaeo)anthropology, historical sciences, genetics and cognitive sciences; if, in other words, the PCT can function as a general framework applicable to all domains that find a direct or indirect expression in language, then it ought to contribute also to the development of a more general and philosophical theory such as the EE, which Nathalie Gontier has defined as "*a general framework based upon evolutionary thinking that is applicable to all domains and products of this evolution*" (Gontier, this volume). Two of the conclusions illustrated in this paper seem to me to encourage this optimism: the conceptual parallelism between the PCT and Gold's general *punctuated equilibrium* theory; and the prospect of a cognitive and operational parallelism between the formation of the human basic grammatical structures and the production of the earliest human lithic tools.

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The extended mind model of the origin of language and culture

Robert K. Logan

Department of Physics, University of Toronto, Toronto, Ontario, Canada
logan@physics.utoronto.ca

Abstract

A model based on the evolution of notated language and chaotics is presented to explain the emergence of language. Language emerges as the bifurcation from percept-based to concept-based thought. Our first words are our first concepts and act as strange attractors for the percepts associated with that concept. The mind is shown to be the brain acting as a percept processor plus language.

1. INTRODUCTION

The evolution of notated language has lessons that can help us understand the origin and emergence of speech. In a study of notated language (McLuhan and Logan, 1977; Logan, 1986) the effects of the phonetic alphabet and literacy on the development of deductive logic, abstract science, codified law, and monotheism were revealed. We showed that these five developments, which emerged between the Tigris-Euphrates Rivers and the Aegean Sea between 2000 and 500 BC, formed an autocatalytic set of ideas that supported each other's development. The alphabet not only served as a convenient way to notate speech it also taught the lessons of analysis (breaking up words into their basic phonemes), coding (writing), decoding (reading) and classification (alphabetization).

From this work emerged the notion that language is both a medium of communication and an informatics tool since the structure of a language influences the way in which people organize information and develop ideas. This work led to the hypothesis that speech, writing, math, science, computing and the Internet represented six independent languages each with its own unique semantics and syntax (Logan, 1995, 2000a). It was shown that these six forms of language formed an evolutionary chain of languages with each

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new language emerging from the previous forms of language as a bifurcation to a new level of order à la Prigogine in response to an information overload that the previous set of languages could not handle.

Writing and mathematical notation arose in Summer as a response to keeping track of the tributes farmers paid to the priests in the form of agricultural commodities as documented by Schmandt-Besserat (1978, 1992). This gave rise to formal schools to teach the skills of reading, writing and arithmetic (the 3 R's), which in turn led to scholars and scholarship giving rise to an overload that science (organized knowledge) was able to deal with. Science gave rise to its information overload, which in turn led to computers and computers gave rise to its information overload, which in turn led to the Internet.

This work on notated language incorporates the goal of evolutionary epistemology (EE) in that it traces the cultural evolution of the knowledge-gaining-processes of notated language, culture, math, science and information processing while at the same time exploiting complex adaptive systems theory. We shall show here how the origin of language itself can be incorporated into this evolutionary epistemological approach.

2. THE EMERGENCE OF LANGUAGE AS THE BIFURCATION FROM PERCEPTS TO CONCEPTS

The results of my previous work gave rise to the question: How did the first language, speech, from which the other languages evolved, arise in the first place? It is from this consideration that my interest in the origin of language problem and literature arose. My earlier work with the evolution of notated language was based on the premise that a new form of language evolved in response to the chaos resulting form the information overload associated with the previous forms of language. In light of this we should anticipate that the origin of speech was also due to a response to chaos and information overload.

As a starting point it was assumed that before the advent of speech hominid thought processes as inherited from our earliest ancestors were percept-based. Donald (1991: 226) makes a similar assumption about the perceptual basis of mimetic culture, the culture of hominids that existed just before the emergence of verbal language. "*The principle of similarity that links mimetic actions and their referents is perceptual, and the basic communicative device is best described as implementable action metaphor.*" (Donald, 1998: 61)

Our earliest human-like ancestors, which we will refer to as hominids, emerged in the savannas of Africa, where they were an easy target for various predators. To defend themselves from this threat as well as to increase their food supply they acquired the new skills of tool making, the control of fire, group foraging, and coordinated hunting. These activities resulted in a more complex form of social organization, which also increased the complexity of their lives. At first, this complexity could be handled through more sophisticated percept-based responses, but at some point the complexity became too great. Percept-based thought alone did not provide sufficient abstraction to deal with the increased complexity of hominid existence. The hominid mind could no longer cope with the richness of its life based solely on its perceptual sensorium. It is conjectured that in the information overload and chaos that ensued a new abstract level of order emerged in the form of verbal language and conceptual thinking.

This idea can be expressed in a slightly different way by making use of Ashby's Law of Requisite Variety (LRV) which has been formulated in a number of different ways. The following two formulations best describe our use of language as a system that we use to represent the environment in which we live. One formulation of Ashby's LRV is "*a model system or controller can only model or control something to the extent that it has sufficient internal variety to represent it.*" (Heylighen and Joslyn, 2001) Another formulation of Ashby's LRV is "*for appropriate regulation the variety in the regulator must be equal to or greater than the variety in the system being regulated.*" (Ibid) By making use of these formulations of Ashby's LRV we are assuming that language is used by humans to regulate or control their social and physical environment.

When the complexity of hominid life became so great that perception and learned reactions to perceptions alone could not provide enough requisite variety to model or regulate the challenges of day to day life a new level of order emerged based on concepts. Percepts arise from our impressions of the external world that we apprehend with our senses and are mediated by neural networks in our brains. Concepts, on the other hand, are abstract ideas that result from the generalization of particular examples. Concepts allow one to deal with things that are remote in both the space and time dimension. If our first words were concepts then language allowed us to represent things that are remote is both space and time and, hence, provide language with what Hockett (1960) defines as displacement.

Concepts also increase the variety with which the brain can model the external world. Percepts are specialized, concrete and tied to a single concrete event but concepts are abstract and generative. They can be applied to many different situations or events. They can be combined with other concepts and percepts to increase variety in ways that percepts cannot. It is for this reason that only humans are able to use their symbols generatively to create new ideas and to make plans for the future. Some animals that have been enculturated are able to comprehend symbols but they do not use these symbols generatively or to express ideas about themselves. They use the symbols indexically in the sense of the way in which Pierce divided signs into icons, indices and symbols.

What, we may ask, was the mechanism that allowed this transition to take place? Assuming that language is both a form of communication and an information processing system it is conjectured that the emergence of speech represented the actual transition from percept-based thought to concept-based thought. The spoken word, as we shall see, is the actual medium or mechanism by which concepts are expressed or represented. We must be very careful at this juncture to make sure that we do not formulate the relationship of spoken language and conceptual thought as a linear causal one. Language did not give rise to concepts nor did concepts give rise to language, rather human speech and conceptualization emerged at exactly the same point in time creating the conditions for their mutual emergence. Language and conceptual thought are autocatalytic and the dynamically linked parts of a dynamic cognitive system, namely, the human mind.

Autocatalysis is the mechanism that Kauffman used to explain the emergence of life: "*A living organism is a system of chemicals that has the capacity to catalyze its own reproduction.*" (Kauffman, 1995: 49) An autocatalytic set of chemicals is a group of organic molecules where the catalyst for the production (or really re-production) of each member of the set is contained within the set itself and as a result the system can become a "*self-maintaining and self-reproducing metabolism*", i.e. a living organism, in the presence of a source of energy and the basic atoms needed to build organic compounds. A key idea in Kauffman's approach is that the members of the autocatalytic set self-organize and, hence, bootstrap themselves into existence as a set with an identity different from the individual members that make up the set.

An autocatalytic process is one that catalyzes itself into a positive feedback loop so that once the process starts, even as a fluctuation, it begins to accelerate and build so that a new phenomenon emerges. The emergence of language and conceptual thought is an example of an autocatalytic process. A set of words work together to create a structure of meaning and thought. Each word shades the meaning of the next thought and the next words. Words and thoughts are both catalysts and products of thoughts and words. Language and conceptual thought is an emergent phenomena. It bootstraps itself into existence.

We will make use of a more generalized form of autocatalysis and suggest that any set of mechanism or ideas that catalyze each other's existence is an autocatalytic set—an autocatalytic set of mechanisms or ideas. Language and conceptual thought form an autocatalytic set because language catalyzes conceptual thought and conceptual thought catalyzes language. Just to better define autocatalysis let us return to our discussion of the alphabet effect in which it was postulated that the phonetic alphabet, codified law, monotheism, abstract science and deductive logic are a set of ideas that are self-supporting.

One can also say that these ideas or ways of organizing thought form an autocatalytic set of ideas.

3. THE RELATIONSHIP OF PERCEPTS AND CONCEPTS

The use of a word transforms the brain from one state to another and replaces a set of percepts with a concept. A word is a strange attractor for all the percepts associated with the concept represented by that word. A word, therefore, packs a great deal of experience into a single utterance or sign. Millions of percepts of a linguistic community are boiled down by the language to a single word acting as a concept and a strange attractor for all those percepts.

The notion that a concept and a word are equivalent was first presented in the Extended Mind model in 1997 (Logan, 1997) and first appeared in print in (Logan, 2000b). Words represents concepts and concepts are represented by words. It is my belief that they emerged together so that words provided a medium by which concepts could be represented, manipulated, spoken about and thought about. This differs dramatically from the position of many linguists like Steven Pinker (2003) who believe that words emerged for the purpose of the communication of concepts that already existed before language emerged. There is no conflict with this view and Pinker's that words and concepts are connected. He recently suggested that "*a word is an arbitrary sign; a connection between a signal and a concept.*" (Pinker, 2003) Where we differ is on the question of which came first the chicken (word) or the egg (the concept). For Pinker first comes the concept and then the word whereas I believe that they co-emerged. The word gave substance to the concept and the concept was represented by the word. The word is more than a symbol or a sign that represents a thing or a concept. To my way of thinking the word is the concept and the concept is wrapped in a word encased in a phonological utterance. To understand the origin of language and words we have to understand the origin of concepts and why they emerged.

A concept in the form of a word links many percepts of an individual and, hence, extends the brains capacity to remember. Words as concepts are a form of *artificial memory* which create *artificial connections*. Words bring order to a chaotic mind filled with the memories of a myriad of experiences. Language is an emergent order.

Concepts are 'artificial or virtual percepts'—instead of bringing the mountain or the percept of the mountain directly to the mind the word brings the mind to the mountain through the concept of the mountain. The concept of the mountain triggers instantaneously all of the mind's direct experiences of mountains as well as instances where the word *mountain* was used in any discourses in which that mind participated either as a speaker or a listener. The word *mountain* acting as a concept and an attractor not only brings to mind all *mountain* transactions but it also provides a name or a handle for that attractor/concept which makes it easier to access memories and share them with others. They speed up reaction time and, hence, confer a selection advantage for their users. And at the same time those languages and those words within a language which most easily capture memories enjoy a selection advantage over alternative languages and words, respectively.

In suggesting that the first words were the strange attractors of percepts does not imply that all words arose in this fashion. It is likely that the first words to appear were the strange attractors of percepts but once a simple lexicon of words and a primitive grammar came into being a new mental dynamic was established. The human mind was now capable of abstract thought and abstract concepts which would be needed to be represented by new words. These new words would not have emerged as attractors of percepts but rather as representations of abstract concepts in the form of grammatical relationships among words. The first words of this nature would have been, in all likelihood, associated with grammar and categorization. Examples of the former would be function words such as: *he, she, this, that, and, or, but, if,* etc., and examples of the words for categorization would be words such as: *animals, people, birds, fish, insects, plants* and *fruits*.

The proposition that human language began with the emergence of words acting as concepts follows a tradition known as the lexical hypothesis which posits that "*the lexicon is at the centre of the language system.*" (Donald, 1991: 250) Language began with a lexicon, which then gave rise to phonological and syntactical structures. Syntactical structures are also concepts. They are concepts that encompass relationships between words just as words are concepts that encompass relationships between percepts.

4. THE COMPLEXITY OF HOMINID EXISTENCE

We are still left with the question, however, what developments in hominid evolution gave rise to the complexity, the information overload, and, hence, the chaos that led to the bifurcation from perception to conception—and the emergence of speech. No single development or breakthrough triggered this event but rather the accumulation of developments that included the use of tools, the control of fire, the larger social settings fire engendered, the social organization required for large group living, food sharing, group foraging and coordinated large scale hunting that resulted from the larger living groups and the emergence of non-verbal mimetic communication as has been described by Merlin Donald (1991) in *The Making of the Modern Mind*.

Deacon (1997) cites a similar set of hominid developments associated with the advent of speech. They include the provision of meat through hunting or scavenging, the use of stone tools for hunting and butchery, and social institutions or organization such as marriage and ritual. Christiansen (1994) and his co-workers (Christiansen and Devlin, 1997; Christiansen and Ellefson, 2002; Christiansen and Kirby, 2003; Christiansen et al., 2005) cite another set of skills associated with the advent of speech, namely, sequential learning and processing. But since tool making and use, social organization and mimetic communication all involve sequential learning and processing the hypotheses of Donald, Deacon and Christiansen are similar. The aspects of hominid life that they allude to create new levels of complexity and result in new skill sets which they believe served as pre-adaptations of language. In my model language arises from this complexity while for Donald, Deacon and Christiansen the new skill sets act as pre-adaptations for language. There is nothing contradictory about my approach and theirs. In fact, they reinforce each other. Both the skill sets acting as pre-adaptations and the bifurcation to a new level of order due to the increase to complexity complement each other and each in their own way contributed to the emergence of language.

One thing is clear, however, percepts no longer had the richness or the variety with which to represent and model hominid experience once the new skills of hominids were acquired. It was in this climate that speech emerged and the transition or bifurcation from perceptual thinking to conceptual thinking occurred. The initial concepts were, in fact, the very first words of spoken language. Each word served as a metaphor and strange attractor uniting all of the pre-existing percepts associated with that word in terms of a single word and, hence, a single concept. All of one's experiences and perceptions of water, the water we drink, bathe with, cook with, swim in, that falls as rain, that melts from snow, were all captured with a single word, water, which also represents the simple concept of water.

In the Extended Mind model it is assumed that the human brain interacting with its environment, its memories of its past experiences in the form of percepts, its intention to communicate and its social community is a non-linear dynamic system. A word operating as a concept acts as an attractor for all of the percepts associated with that word. An attractor is a trajectory in phase space towards which all of the trajectories of a non-linear dynamic system are attracted. The meaning of the word being uttered does not belong simply to the individual but to the community to which that individual belongs.

Furthermore the meaning of the word at any given instance emerges from the context in which it is being used. The attractor is a strange attractor because the meaning of a word never exactly repeats itself. The trajectories of a strange attractor never meet even though they come infinitesimally close to each other. It is the same with a word. The meaning of a word fluctuates about the strange attractor but it is never exactly the same because the context in which the word is being used is always different. The context includes the other words in the utterance, who made the utterance, the social context in which the utterance was made, and the medium in which the utterance was made. Given that the medium is the message as was explained above the meaning of the word will be subtly effected according to whether the word was spoken, whispered, written, telephoned, telegraphed, emailed, or appeared on a Web site.

Our use of the word utterance in the above paragraph is an example of how context shifts meaning. Utterance usually refers to the oral production of language but in the context we just used it took on the meaning of the general construction of a sentence independent of the medium used to express it. Although in most cases a word moves around an attractor in the phase space of meaning from time to time a word can bifurcate into two meanings. An example of this is the appropriation of the words hot and cool to refer to two different styles of jazz, namely, dixieland and bebop, respectively. The word cool used in jazz further bifurcated to add the meaning avante garde, *with it*, or hip. Hip is another example of a word that bifurcated.

The fact that we chose to identify words as strange attractors reflects the fact that words in the contexts of an utterance have multiple even ambiguous meanings or multiple simultaneous perspectives to use the language of Tomasello (1999: 8–9). Within the context of spoken language the ambiguity is reduced because the prosody and accompanying gestures and hand movements add additional meanings to the words being spoken. Within the context of written language without these extra-verbal signals the ambiguity of a word is at its greatest. Within the context of mathematics and science in which terminology is given precise definitions the ambiguity of words is at a minimum. The attractors that represent mathematical and scientific terms approach fixed point attractors but are not totally fixed point attractors. There is always a bit of fuzziness about even mathematical and scientific terms which can be attributed to the differences of opinions of mathematicians and scientists, on the one hand, and to Gödel's Theorem in the realm of math and the Heisenberg uncertainty principle in the realm of quantum physics, on the other hand.

Spoken language and abstract conceptual thinking emerged at exactly the same time as the bifurcation from the concrete percept-based thinking of prelingual hominids to conceptual-based spoken language and thinking. This transition, an example of punctuated equilibrium, was the defining moment for the emergence of the fully human species Homo sapiens sapiens. This discontinuous transition illustrates Prigogine's theory of far from equilibrium processes and the notion that a new level of order can suddenly emerge as a bifurcation from a chaotic non-linear dynamic system (Prigogine and Stengers, 1984; Prigogine, 1997).

Dunbar (1992) has also made a link between the advent of language and the complexity of hominid existence, as measured by the size of the social group. He suggested that language replaced grooming as a way of creating social cohesion as the size and complexity of the social group increased. "*The principle function of language was (and is!) to enable the exchange of social information ('gossip') in order to facilitate bonding in larger, more dispersed social groups.*" (ibid: 98)

5. THREE PREVERBAL FORMS OF PROTO-LANGUAGE: TOOL MAKING, SOCIAL INTELLIGENCE AND MIMESIS

The transition from percept-based thinking to concept-based thinking represented a major discontinuity in human thought. During this period, hominids developed the set of survival skills associated with tool making and use, the control of fire, co-operative social structures and organization, large scale coordinated hunting, and mimetic communication (Donald, 1991). Based on the work of Merlin Donald these major breakthroughs in hominid cognition can be thought of as the emergence of three distinct percept-based preverbal proto-languages:

(1) manual praxic articulation (or tool making and use),
(2) social organization or the language of social interaction (which is sometimes characterized as social or emotional intelligence),
(3) preverbal communication which entails the use of hand signals, mime, gesture and prosodic vocalization which Donald (1991) defines as mimetic communication.

Before proceeding with my analysis we need to be clear about the use of the term protolanguage which Derek Bickerton (1990) coined to describe a stage in the development of human language in which a lexicon of a small number of words existed without syntax and utterances were confined to less than five words. I actually quite independently used the term proto-language with a hyphen before becoming acquainted with Bickerton's work in a 1997 paper (Logan, 1997) to describe what will now be referred to as the *three percept-based preverbal proto-languages* listed above.

These three forms of preverbal activities identified by Donald as elements of mimetic culture are actually proto-languages although he never spoke of them in these terms. As Bickerton has already co-opted the term protolanguage to describe the first stage of verbal language I have altered my use of the term proto-language and will describe toolmaking, social organization and mimetic communication as three forms of *percept-based preverbal proto-language*.

In a certain sense these three forms of preverbal proto-language as more proto than Bickerton's protolanguage because they are earlier. In summary it is suggested that preverbal proto-language as identified by Donald evolved into verbal Bickertonian protolanguage and then into full verbal language as the following time sequence indicates:

(1) toolmaking,
(2) social intelligence,
(3) mimetic communication (hand signal, gesture, body language and vocalization),
(4) protolanguage (a limited verbal lexicon without syntax as defined by Bickerton) and
(5) full verbal language (with a lexicon and syntax).

The reason that it is suggested that the first three breakthroughs in hominid cognitive development can be understood as three percept-based preverbal proto-languages is that they each represented a primitive form of communication and information processing, the two basic functions of language. Mimesis, according to Donald, "*establishes the fundamentals of intentional expression in hominids, without which language would not have had an opportunity to evolve such a sophisticated, high-speed communication system as modern language unless there was already a simpler slower one in place*" (Donald, 1998: 61).

The three preverbal proto-languages listed above were, according to Donald, the cognitive laboratory in which the skills of generativity, representation and communication developed and, hence, were the source of the cognitive framework for speech. They also entail sequential learning and processing and, hence, following the ideas of Christiansen (1994) could have served as pre-adaptations for speech.

Justification for regarding the mimetic skill set Donald identifies as preverbal proto-languages is that each one possesses its own unique primitive form of semantics and syntax, protosemantics and protosyntax, if you will. The protosemantics of manual praxis or tool-making and tool-use are the various components that go into making of the tool, i.e., the materials and the procedures needed to create and use the tool. The tools themselves become protosemantic elements in the preverbal proto-language of tool use. The protosyntax of toolmaking and tool-use is the order or sequence in which the procedures for making and using the tools are carried out. If the correct order or sequence is not adhered to then the task to be completed will not be accomplished.

If, as we have postulated in *The Sixth Language* (Logan, 2000a), a new language emerges when there is some form of information overload, then we should be able to identify the chaos or information overload that led to the emergence of the preverbal proto-language of tool-making and tool-use. Perhaps it was the flood of extra information that the earliest hominids had to deal with in order to survive as bipeds in the savannah where the protection of living in the tree tops was no longer available. Tools were created to deal with the new challenges of living at ground level where there were far more dangers than in the tree tops.

The skills associated with toolmaking presumably led to the control of fire and to transporting it from one site to another. The control of fire in turn contributed to new and more complex social structures as nuclear families banded together to form clans to take advantage of the many benefits that fire offered such as warmth, protection from predators, tool sharpening and cooking, which increased the number of plants that could be made edible, killed bacteria and helped to preserve raw foods such as meat. These larger social structures bred a new form of information overload because of the increased complexities of social interactions and organization. In this environment a new preverbal proto-language of social interactions emerged with its protosemantics of social transactions which included greetings, grooming, mating, food sharing and other forms of co-operation appropriate for clan living. The protosyntax of the social organization or intelligence included the proper ordering or sequencing of these transactions in such a way as to promote social harmony and avoid interpersonal conflict, and, hence, contribute to the survival and development of hominid culture.

The overload of interacting with many people and carrying out more sophisticated activities led to the need for better communications to better coordinate social transactions and co-operative activities such as the sharing of fire, the maintenance of the hearth, food sharing and large scale coordinated hunting and foraging. From the chaos of this complexity emerged the preverbal proto-language of mimetic communication.

The protosemantics of mimetic communication, the third preverbal proto-language, consisted of the following elements: the variety of tones of non-verbal vocalization, facial gestures, hand signals and miming actions (or body language). The protosyntax of this form of communication is the sequencing and coordination of these elements. Combining a gesture and a vocal tone would have a different meaning than the same tone followed by the gesture after some delay or the gesture followed by the tone. As the syntactical complexity of mimetic communication grew and became more sophisticated it set the stage for the next development in hominid communication, namely, verbal language in the form of speech which vestigially incorporates the elements of mimetic communication. It is not the literal meaning of words alone which convey the message of spoken language but the tone of the words, the way they are inflected, as well as the facial gestures, hand motions and body language which accompany them.

Embedded in the syntax of each of the three preverbal proto-languages of toolmaking, social intelligence and mimetic communication there are generative grammars which allow:

(1) different ways of articulating tools and manual praxis to carry out a variety of new tasks as new challenges arise;
(2) the creation of new forms of coordination and social cohesion to meet the infinite variety of challenges life presents including the navigation through different forms of social conflict, the variety of which is endless;
(3) the expression of a large number and shades of meaning and feelings through mimetic communication.

Starting with the manufacture and use of tools hominids began to develop the capability of generativity essential for verbal language. Employing the correct syntax of the preverbal proto-languages, i.e. doing things in the proper order or sequence served as the pre-adaptation for the generative grammar of verbal language. This model supports Chomsky's theory that humans possess a generative grammar that makes the rapid and universal acquisition of speech by young children possible. It also provides an alternative explanation to Chomsky's notion that the generative grammar is somehow magically hard wired into the human brain.

Merlin Donald's (1991) work suggests that the generative grammars for the preverbal proto-languages of toolmaking (or manual articulation), social organization (or social intelligence) and mimetic communications served as a pre-adaptation for the generative grammar of spoken language.

> Mimetic skill represented a new level of cultural development, because it led to a variety of important new social structures, including a collectively held model of the society itself. It provided a new vehicle for social control and coordination, as well as the cognitive underpinnings of pedagogical skill and cultural innovation. In the brain of the individual, mimesis was partly the product of a new system of self-representation and mostly the product of a supramodular mimetic controller in which self-action may be employed to 'model' perceptual event representations. Many of the cognitive features usually identified exclusively with language were already present in mimesis: for instance, intentional communication, recursion, and differentiation of reference. (ibid: 199–200)

Like Donald, Deacon (1997) also suggests an association of the emergence of speech with toolmaking:

> The appearance of the first stone tools nearly 2.5 million years ago almost certainly correlates with a radical shift in foraging behaviour in order to

> gain access to meat. And this clearly marks the beginnings of shift in selection pressures associated with changes in the brain relevant for symbolic communication. (ibid: 386)

While Deacon (1997: 400–401, 406) does not make use of the concept of social organization or intelligence he does introduce the notion that changes in the social dynamics of hominids led directly to symbolic communication and that marriage itself was one of the first forms of symbolic communication in which the parties to the marriage were themselves symbols.

While Donald speaks of speech emerging from mimetic communication Deacon in a slightly different tack sees speech as assimilating these features and co-evolving with them.

> With the final achievement of fully articulate speech, possibly as recently as the appearance of anatomically modern Homo sapiens just 100,000 to 200,000 years ago, many early adaptations that once were essential to successful vocal communication would have lost their urgency. Vestiges of these once-critical supports likely now constitute the many near-universal gestural and prosodic companions to normal conversation. (ibid: 364)

As to determining whether Deacon or Donald provide the most accurate model of the relationship between toolmaking, social organization and mimetic communication and speech there is no scientific criteria for making a choice. It is difficult if not impossible to falsify their propositions because data from the events they describe is so scarce. We must resort to the Kuhnian (1972) notion that the choice of rival descriptions will have to be based on what the reader finds most compelling.

6. THE ORIGIN AND EVOLUTION OF THE EXTENDED MIND

An attempt has been made to develop insights into the role that language has played in the development of human thought and culture by combining ideas on the nature and function of language, the concept of bifurcation from chaos theory and Merlin Donald's (1991) notions of evolutionary psychology. Building on these ideas one can tackle the age old question of the relationship of the human mind and the brain. For some psychologists this is a non-problem as they believe that the brain and the mind are synonymous, just two different words to describe the same phenomena, one derived from biology, the other from philosophy. For others there is a difference. Some define the mind as the seat of consciousness, thought, feeling and will. Those processes of which we are not conscious, such as the regulation of our vital organs, the reception of sense data, reflex actions and motor control, on the other hand, are not activities of our mind but functions of our brain.

There is no objective way to resolve these two different points of view but a useful distinction can be made between the mind and the brain based on our dynamic systems model of language as the bifurcation from concrete percept-based thought to abstract concept-based thought. It is, therefore, assumed that the mind came into being with the advent of verbal language and, hence, conceptual thought. This transition did not occur with the first emergence of words in the form of Bickertonian protolanguage which contained a modest lexicon but no syntax. This transition to the human mind likely took place with the emergence of syntax approximately 50–100 thousand years ago, which allowed for full generativity and the ability of language to represent all aspects of the world.

Syntactilized verbal language extended the effectiveness of the human brain and created the mind. Language is a tool and all tools, according to McLuhan (1962; 1964), are extensions of the body that allow us to use our bodies more efficiently. Language is a tool which extended the brain and made it more effective thus creating the human mind which I have termed the extended mind and have expressed in terms of the equation: mind = brain + language. It was the following passage from *Understanding Media* that inspired this hypothesis:

> It is the extension of man in speech that enables the intellect to detach itself from the vastly wider reality. Without language, Bergson suggests, human intelligence would have remained totally involved in the objects of its attention. Language does for intelligence what the wheel does for the feet and the body. It enables them to move from thing to thing with the greatest ease and speed and ever less involvement. Language extends and amplifies man but it also divides his faculties. His collective consciousness or intuitive awareness is diminished by this technical extension of consciousness that is speech. (McLuhan, 1964)

The human mind is the verbal extension of the brain, a bifurcation of the brain which vestigially retains the perceptual features of the hominid brain while at the same time becoming capable of abstract conceptual thought. Bickerton (1995: 150) reaches a similar conclusion and makes a distinction between a *brain-state* and a *mind-state*.

The emergence of syntactilized language also represents, for me, the final bifurcation of hominids from the archaic form of Homo sapiens into the full fledged human species, Homo sapiens sapiens. Crow reaches a similar conclusion. He points out that pictorial art demonstrating a capacity for representation, an essential element of human language can only be traced back to around 90,000 years ago and was absent for both Neanderthal and Homo Erectus. Citing Stringer and McKie (1996), he concludes, "*The parsimonious conclusion (because it links the distinctive characteristic of the species to its genetic origin) is that the origin of language coincided with the transition to modern Homo sapiens dated to somewhere between 100,00 and 150,000 years ago.*" (ibid: 93)

Humans are the only species to have developed verbal language and also to have experienced mind. This is not to deny that our ancestors, the earlier forms of hominids, experienced thought and consciousness. Their thought patterns, however, were largely percept-based and their brains functioned as percept processing engines operating without the benefit of the abstract concepts which only words can create and language can process. It follows that animals have brains but no minds and that the gap between humans and animals is that only humans possesses verbal language and mind.

In summary, the emergence of language represents three bifurcations:

(1) the bifurcation from percepts to concepts,
(2) the bifurcation from brain to mind and
(3) the bifurcation from archaic Homo sapiens to full fledged human beings, Homo sapiens sapiens.

These three bifurcations are not necessarily simultaneous. Bickerton (1990, 1995) claims that protolanguage in which the first words were used symbolically emerged with Homo erectus which means the first bifurcation can be dated to approximately 2 million years ago. The second and third transitions, on the other hand, can be dated to the emergence of fully syntactilized language which occurred only 100–150 thousand years ago and seems to be correlated with the explosion of human culture and technological progress of that time period (Bickerton, 1995: 65).

This hypothesis or model provides a possible explanation of the fate of Neanderthals who had a slightly larger brain than Homo sapiens sapiens but who, it seems, did not use spoken language. This conclusion, disputed by some, is based on the analysis of fossil remains which reveal that Neanderthal's vocal tracts were not as well developed as those of humans. Neanderthals who survived for over a hundred thousand years were dominated by their human rivals and disappeared in Europe after only 10,000 years of living side by side with humans. Obviously the mind, which combines the features of both the percept engine which is the brain and the concept generator of verbal language is a more powerful instrument of reasoning and thought than the brain alone. Once language emerged the size of the brain alone was no longer the sole determining factor in intelligence as had been the case for the evolution of the hominid brain.

Empirical data suggests that the size of the brain alone without language does not give rise to a particularly smarter brain. Bickerton points out that,

> when the brain doubled in size, hominids did not get twice as smart. Artefact production and behavioural changes from Homo habilis to Neanderthal are insignificant compared to those found once our own species emerged, and unless there is no relationship whatsoever between intelligence and the products of intelligence (including tools and behaviour), an enlarged brain did not, in and of itself, significantly enhance the former. (Bickerton, 2000: 271)

What did enhance the former, in my opinion, was language.

Deacon has developed an alternative scenario to explain the demise of Neanderthal. He claims they perished as a result of a disease that the Homo sapiens arriving from Africa brought with them for which Neanderthals had no resistance in much the same way Amerinds perished from small pox carried to North America by Europeans. While this is certainly a possibility, history has shown that even during the most virulent pandemics a certain percentage of the population always survived. In humans there are roughly 30 genes known as human leukocyte antigens which vary wildly among people and allow a uniform population to survive a plague or an epidemic.

As the brain of hominids increased in size and complexity certain biological limits were reached. The head of an infant could only become so big and pass through the hips of a woman if humans were also to retain there capacity for mobility, an important factor for survival. One evolutionary strategy for packing more reasoning power into the small space of the head was the development of convolutions of the brain; another was the gender differentiation of the male and female anatomy and the specialization of gender tasks. The females had broader hips for childbearing large headed babies and tended to spend more time attending to the tasks associated with the hearth while the males remained narrow hipped and roamed about as the hunters and defenders of the family from marauders.

Another reason for limits on the size of the brain comes from energy considerations according to Dunbar is as follows:

> Brains are extraordinarily expensive organs to evolve and maintain. The average brain weighs about 2% of adult body weight, yet consumes something approaching 20% of the body's total energy intake. . . . Since brains do not come for free, some very powerful selection pressure is required to make it worth a species' while evolving them. Given this, having any space at all dedicated to language (or speech!) must add measurably to the costs incurred by the individual, and would be selected against unless

> countervailing selection pressure made language advantageous. (Dunbar, 1992: 93)

According to the Extended Mind model language acting as an extension of the brain allowed human intelligence to increase without an increase in brain size.

> Language (whatever the value of its emergent properties) was not itself the driving force behind the evolution of the superlarge human brain. This would explain why the key language areas (Broca's, Wernicke's and associated areas) are significantly smaller in volume than those areas associated with social skills and theory-of-mind abilities (the prefrontal cortex). (Dunbar, 1992: 103)

This observation by Dunbar supports our notion that language extends the brain into a mind which operates more efficiently because language accesses associations automatically and triggers memories more efficiently than the brain's neural nets would without the cues from language.

By making use of a facility to create abstract and symbolic thought at the conceptual level the effectiveness of the human mind was able to make a quantum leap forward without making large incremental energy demands. Our claim is that symbolic conceptual thinking is more efficient than concrete perceptual thinking and, hence, there was a selection pressure in favour of the emergence of language. Language extended the brain into a mind capable of symbolic thought. Dunbar (ibid: 104) concurs with our suggestion that the emergence of speech and the human race were concurrent: "*The evolution of language seems to correspond in time to the emergence of our own species, Homo sapiens.*" Bickerton (2000: 276) expresses a similar thought, "*It may be hypothesized that a larger number of the first type (those pushing at the boundaries of protolanguage) appeared in southern Africa, probably within the last two hundred thousand years, and that it was this chance agglomeration that launched our species.*"

7. CONCLUSION

After all the physical mechanisms for increasing human intelligence by increasing head size and brain size had been exhausted nature conspired through chaos theory to increase hominid intelligence with a software rather than a hardware stratagem. The software was verbal language from which emerged the human mind and conceptualization. Words encode basic concepts and, hence, allow for the more efficient processing of information and knowledge. Conceptualization allowed for the creation of more words and new metaphors to achieve still higher levels of conceptualization and representation. Concepts and words formed a dynamic systems bootstrap creating the conditions for their mutual and dynamic development. In other words, language and thought formed an autocatalytic system. A possible metaphor for the role language plays in enhancing brain function is the disk doubler or zip drive used to provide a microcomputer (an artificial brain) with a compact way to store and process data and information. Language is the brain's zip drive converting it into an extended mind.

By combining complex adaptive systems theory together with elements from hominid anthropology, linguistics and language acquisition we have provided a possible model for the emergence of verbal language and abstract conceptual thought which is unique to genus Homo. As to future studies it is hope that this approach can be better synthesized to more traditional EE approaches.

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From changes in the world to changes in the words

Jean-Philippe Magué

Laboratoire Dynamique Du Langage, Institut des Sciences de l'Homme, Université Lyon 2, Lyon cedex, France
jean-philippe.mague@etu.univ-lyon2.fr

Abstract

This paper deals with the evolution of the lexicon in a changing environment. We adopt Mufwene's (2001) metaphor of 'language as species' that explains evolution of languages as differential selection of features in languages' feature pools. We propose a multi-agent model and use it to explore the role of different constraints on the feature selection process. We show that constraints are indeed competing and that one of them is the major constraint in natural selection, viz., fitness to the environment.

1. INTRODUCTION

According to the myth of Babel, diversity in human languages is due to God's anger toward the arrogance of humans that were trying to build a tower high enough to reach heaven. Such defiance against divine power being unacceptable, God broke mankind's linguistic unity. Unable to understand each other and thus divided, humans gave up with their tower project and populations spread over the world, leaving intact the domination of God on heaven.

This myth broke down in favor of evolutionary views of language as early as the mid-18th century, decades before the diffusion of evolutionarism into natural sciences and thus long before Darwin's theory (Tort, 1980). This anteriority had a double consequence: on the one hand biologists, aware of linguists' interests in evolution, used the language metaphor to explain natural evolution of species (Darwin, 1859), while on the other, linguists, seeking a formalization of language evolution, followed developments of the biological theory (Schleicher, 1863; see Ben Hamed and Darlu, 2005 for a review).

When one mentions the evolution of language, a distinction has to be made between the evolution of the language faculty and the evolution of languages. The evolution of the language faculty is a field of research seeking to ascertain when, how and why our species has developed this unique and complex

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communication system, viz., Language. This field is growing rapidly and relies strongly on neo-Darwinism since Pinker and Bloom (1990) argued for the necessity of referring to natural selection in explanations of language origin. This biological evolution has nothing to do with the evolution of languages, which is a cultural process taking place on timescales, which are insignificant to natural evolution. Nevertheless, parallels between biological and cultural evolutions may be drawn and metaphors formulated since similar mechanisms drive both evolutions. This use of a biological metaphor for language evolution can be found in Mufwene (2001) who considers languages as species and idiolects as individuals. Each language has a feature pool similar to species' gene pool in which idiolects pick out their characteristics. Language evolution is then due to the selection by learners of features in competition from the feature pool (learners may modify features, providing then new features to the pool, with the consequence that this evolution falls into the Lamarckian paradigm). Selection criteria proposed by Mufwene are primarily frequency of the features and cognitive and structural constraints. The main thesis of this paper is that when we look at lexical items, there is a very specific constraint on the selection: selected items are items that best fit speakers' environment.

The rest of the paper is organized into four sections: in the following section we describe the semantic framework upon which our work is grounded. Then we describe the model we developed in order to study dynamics of the lexicon. The next section relates four simulations run with the model, and in the final section the results obtained are discussed.

2. SEMANTICS, CATEGORIES AND CONCEPTS

2.1. Semantics

Providing an account of how words get their meaning is a problem far from trivial. The 20th century has seen broadly three attempted solutions coming from three different fields: philosophy, linguistics and psychology.

The philosophical account of semantics, called formal semantics or veri-conditional semantics, is due to the revolution of logic that happened at the end of 19th and the beginning of the 20th centuries when Frege and others realized that Aristotle did not say all that can be said about logic. Assimilating formal and natural languages, they faced the problem of how the symbols of their expressions refer to something. The answer that formed the groundwork for formal semantics was provided by Wittgenstein (1922): the meaning of an expression is its truth conditions, i.e. how the world should be so that the expression is true. This semantic tradition is still very active and its most achieved proposition is probably Montague's semantics (Montague, 1973).

Linguists' interest in semantics is clearly natural. The Saussurian structural wave (de Saussure, 1915) that flooded linguistics and more generally humanities (at least in Europe) reached semantics and inspired structural semantics. According to the structural account, a language is a closed system and a sign, composed of a *signifié* and a *signifiant*, receives its meaning from the relations the *signifiant* maintains with the other *signifiants* of the language.

The psychological account of semantics, viz., cognitive semantics, has also been proposed by linguists. It is much more recent since the pioneering contributions are only a quarter of a century old (Fillmore, 1982; Lakoff, 1987; Langacker, 1987). It is psychological in the sense that meaning of words and expressions are mental entities. Cognitive semantics belongs to the more general stream of cognitive linguistics that rules out the independency of language and embeds it firmly into cognition. Our cognitive apparatus allows us to form mental representations of the world which may serve as meaning of words and expressions. This approach is summarized in Sweetser (1990: 1): "*Language is systematically grounded in human cognition and cognitive linguistics seeks to show exactly how. The conceptual system that emerges from everyday human experience has been shown [...] to be the basis for natural-language semantics [...]* ". This is the line of semantics, which we adopt here. The notions of categories and concepts are thus critical for us, and consequently the following section aims at detailing them.

2.2. Categories and Concepts

2.2.1. The classical view

Grouping things together is an activity that we cannot avoid doing. We cannot see a bed without thinking that it is a bed, we cannot write with a pen without knowing that we are using a pen. Categorization is one of our basic cognitive skills and is used in most (if not all) of our activities.

Our ability to recognize objects of the world as members of categories is so automatic and unavoidable, that people have long thought that objects really belong to categories, which somehow exist independently of us. This view is known as the classical view and can be traced back to Aristotle. Aristotle's conception of the world was hierarchical: things belong to categories, which are in turn grouped into supercategories, and so on, with the category 'Being' at the top of the hierarchy. At any level of this taxonomy, categories are mutually exclusive and they sum up together to form the universe: an object belongs to one and only one category. It follows that given an object and a category, either this object belongs to this category, or it does not. A category is defined in term of the characteristics that all of its members have in common. Each of these characteristics is necessary for an object to belong to the category, and they are all together sufficient to provide the membership to the category.

2.2.2. The Roschian revolution

This view of categories prevailed for almost 23 centuries. The first major claim against the classical view came from philosophy with Wittgenstein (1953). Wittgenstein noticed that it is not always the case (almost never in fact), that membership is due to a set of common characteristics shared by all the members of a category and only them. He illustrated this fact with the famous example of the category GAME. If we look at the characteristics of games, we find that many of them are shared by many games, but none is present in all the games. Most games involve different players, but not all; some games rely on particular skills, others on chance and others on both; many games finish with a winner, but for others the notion of 'winning' is meaningless. Rather than a set of common characteristics, what characterizes the members of a category is what Wittgenstein called *family resemblances*. Members of a category are similar to each other in many ways, but none of these ways make them similar all together. As a consequence of the Wittgensteinian view of the categories, we are no longer provided with a criteria (a set of necessary and sufficient conditions) to decide whether an object belongs to a category or not. It follows that the boundaries of the categories are not clear as in the classical view but fuzzy and extendable. An illustration of the fuzziness of boundaries can be found in the beginnings of surrealism which was accepted as art by some, while strongly refused by others. And to illustrate the extendableness of boundaries, it is interesting to note that the debate of membership of surrealism to art is long over and is now considered a typical art form of the first half of the 20th century. One fundamental implication of Wittgenstein's conception of categories is that they are no longer seen as abstract entities that exist independently of us. The fuzziness of their boundaries and the impossibility to define objective means to make judgment about membership clearly establish categories as psychological entities.

The next major attack against the classical view (and probably the most important) marked the shift of categorization from philosophy to psychology with the empirical work of Eleanor Rosch (Rosch and Mervis, 1975). Rosch's contribution to categorization, known as *prototype theory*, addresses both the status of certain members within categories and the status of certain categories within the taxonomy. In Aristotle's hierarchy of categories, no level is given particular consideration. A dog is equally a Dalmatian, a dog, a mammal, an animal and so on. What Rosch pointed out, is that it not the case at all. Before being a Dalmatian or a mammal, a dog is a dog. The category DOG has a special cognitive status. It is a *basic level* category. These categories, like CHAIR, TREE, are more naturally used when we categorize things. They are learned and remembered more easily, we have motor actions associated with them and we can form mental images of them. A theory of categorization must account for that, but the classical view cannot.

Rosch also established that we do not treat all the members of a given category equivalently: some of them are more representative of the category than others; members differ in their *typicality*. For example, in the category BIRD, *robin* is a better example than *chicken*, which is a better example than *penguin*. Best examples of a category are called *prototypes*. Effects of prototypicality have been shown in many different kinds of tasks (direct rating, mental chronometry and so on, cf. Lakoff, 1987: Chapter 2, for a review). The classical view cannot give any account for these prototype effects, given that the set of necessary and sufficient conditions that defines membership does not give a special status to any member.

One consequence of abandoning the classical view is that categories have to be attributed a new ontological status. Categories are not objective and external entities, but subjective and internal. There is no objective category BIRD that exists independently of cognitive organisms (which does not mean that the world has no structure). Cognitive organisms create concepts, i.e. representations of the world, which capture the similarities of the world they live in. The world is continuous and concepts try to give a discrete account of it. Objects more or less match the concepts, causing the prototype effect.

Let us consider an entity that we categorize as BIRD; we would categorize the parents of that entity as BIRD too, as we would do with the parents of the parents, and with the parents of the parents of the parents and so on. But if we consider the ancestors of that entity that lived 200 millions years ago, we would categorize them as DINOSAUR. There is a continuum between the entity that lives now and its ancestors. There is no necessary and sufficient condition for being a bird that one entity would not have verified (and hence been a dinosaur) and that its child would have verified (and hence been a bird). Instead of one absolute and objective category, there are as many subjective categories as cognitive organisms are able to develop. These categories represent the world in which the organism does live, and that is why Archaeopteryx is a rather non-typical bird.

3. MODEL OF LEXICAL EVOLUTION

In this section, we present our model of lexical evolution which falls into the evolutionary linguistics framework. Evolutionary linguistics aims to explain language origin and evolution by simulating community of interacting speakers. From their interactions, emerge and evolve particular aspects of language such as lexicon (e.g. Steels, 1998), phonology (e.g. de Boer, 2000), syntax (e.g. Kirby, 2000). (See Cangelosi and Parisi, 2001, for general introduction to evolutionary linguistics.) In particular, our model is related to works of Steels (1998), Vogt (2003) and Smith (2003). (See Section 5 for details).

In order to fully describe the model, we have to specify how the speakers, their interactions, their social relationships and their environment are modeled.

3.1. Cognitive Architecture of the Speakers

3.1.1. Conceptual spaces

Let us take four balls, two blue, a big one and a small one, and two red, a small one and a big one as well. When we turn to the relations of similarity between these four objects, we face a dilemma: would we judge the similarity according to the size, grouping together the big balls on the one hand and the small ones on the other? Or would we group according to the color, having the two red balls in one group and the two blue in the other?

This example reveals the (trivial) fact that there are many ways of judging similarity between objects. Gärdenfors (2000) has named these different ways *quality dimensions.* We have seen that shape and color are quality dimensions, [1] but we could cite many others: weight, time and so on. Quality dimensions may vary on their topological structure: weight is isomorphic with the non-negative real numbers, while the hue dimension of colors is isomorphic with a circle. Some quality dimensions are innate (i.e. biology based), others are acquired (i.e. culture based): perception and representation of colors are universal (Berlin and Kay, 1969), while representation of time is linear in some cultures but circular in others.

Together, quality dimensions form *conceptual spaces.* The conceptual spaces framework allows us to define some crucial notions for our problem. Perception of an object is defined as the act of determining the value of that object on each quality dimension, i.e. forming a point in the conceptual space that represents the object. A concept (i.e. a mental representation that determines the categorization of a perceived object) is a region of a conceptual space. Learning is creating a new concept, or modifying an existing one.

3.1.2. Concepts

In this section, we review the technical details of concept modeling in a conceptual space, which differ from Gärdenfors (2000). In the rest of this paper, all quality dimensions are isomorphic to the real numbers, and thus conceptual spaces are multi-dimensional Euclidian spaces.

As we have seen in Section 2, categories are not clear-cut sets of objects. Members of categories vary in their typicality, ranging from objects that are prototypes of the category, to objects for which membership is not an easy question. Mathematics provides us with a very useful tool for handling this

[1] Color is actually composed of three dimensions: hue, saturation and brightness.

kind of set: the fuzzy sets theory. More precisely, fuzzy arithmetic will be our scalpel to shape concepts in conceptual spaces. Fuzzy numbers have been introduced to model expressions such as “about 50” (Dubois and Prade, 1978; Kaufman and Gupta, 1984; Mareš, 1994). Fifty is certainly ‘about 50’, 49 and 51 are very likely to be ‘about 50’, but 65 and 842 are probably not “about 50” (what exactly is “about 50” depends on what we are talking about). In fuzzy arithmetic, a fuzzy number F is defined by its characteristic function $\mu_F : \Re \to [0; 1]$. In our case, we will consider an extension of fuzzy numbers in n-dimensional spaces, i.e. we will consider fuzzy vectors. The characteristic function of a fuzzy vector has to verify the following properties:

(i) $\exists x_0 \in \Re^n, \quad \mu_F(x_0) = 1,$
(ii) $\forall x_1, x_2 \in \Re^n, \ \forall \lambda \in [0; 1], \quad \mu_F(\lambda \cdot x_1 + (1 - \lambda) \cdot x_2) \leq \max(\mu_F(x_1), \mu_F(x_2)),$
(iii) $\{x \in \Re^n, \mu_F(x) \neq 0\}$ is bounded.

In the framework of concept modeling, the μ_F function indicates the membership of objects. If for an object x, $\mu_F(x) = 1, x$ is then a prototype of the category. If $\mu_F(x) = 0, x$ does not belong to the category. Intermediate values indicate the degree of typicality. Property (i) may be interpreted by the fact that each concept has a prototype which is an object with a certain membership. Property (ii) expresses that if an object x_1 is more similar to the prototype than an object x_2, then x_1 is more typical than x_2. Property (iii) expresses that if an object is dissimilar enough from the prototype, it does not belong to the concept. Figure 1 illustrates a characteristic function in $\Re$.

Directly handling or modifying the characteristic function of a fuzzy number is not very practical. For that reason many ways of representing fuzzy numbers have been introduced. Here, we will use an approach proposed by

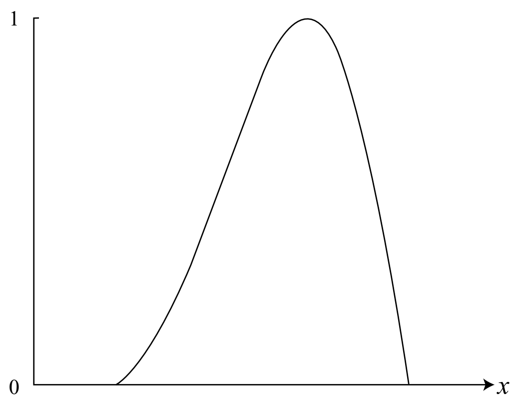

Figure 1. A characteristic function of a fuzzy number.

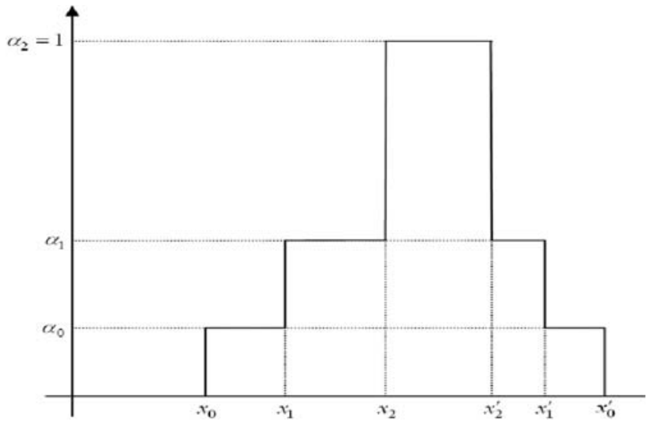

Figure 2. Characteristic function μ_F of a fuzzy number F defined by $\{([x_0; x'_0], \alpha_0), ([x_1; x'_1], \alpha_1), ([x_2; x'_2], \alpha_2)\}$.

Kaufman and Gupta (1984), which relies on the notion of *α-cut*. F_α is the α-cut of F if and only if $F_\alpha = \{x \in \Re, \mu_F(x) \geq \alpha\}$. A fuzzy number F can be defined by the set $\{F_\alpha, \alpha \in]0; 1]\}$. Moreover, any set of N pairs:

$$\{([x_n; x'_n], \alpha_n), 0 \leq n < N, [x_{n-1}; x'_{n-1}] \subset [x_n; x'_n], 0 < \alpha_{n-1} < \alpha_n \leq 1, \alpha_{N-1} = 1\},$$

define a fuzzy number F which step-shaped characteristic function is (see Figure 2):

$$\mu_F(x) = \begin{cases} 0 \text{ if } x \notin [x_0; x'_0] \\ 1 \text{ if } x \in [x_{N-1}; x'_{N-1}] \\ \alpha_n \text{ if } x \in [x_n; x'_n] \quad \& \quad x \notin [x_{n+1}; x'_{n+1}] \end{cases}.$$

Fuzzy numbers defined by the mean of α-cut can easily be generalized to fuzzy vectors in N-dimensional spaces by using N-dimensional hyperspheres instead of intervals. Each α-cut is then defined by a center and a radius. This is how concepts are represented in our model. The number of α-cuts used for representing the concept is a parameter of the model (in subsequent simulation, α is set to 10). Each concept C is given a confidence degree, $U_C \in [0; 1]$, which represents the confidence of the speaker in the usefulness of the concept. Each concept is also tagged with a word, w_C, and stands for the meaning of that word. We will use the term 'conceptual structure' to refer to a speaker's conceptual space and concepts together. In all the simulations presented in this article, speakers are endowed with a two-dimensional conceptual space.

3.2. Interactions

In our model speakers communicate about the objects around them and from their interactions emerges and evolves a lexicon. This is made possible because after each interaction, speakers modify their conceptual space in order to take into account the result of the interaction. Let us first describe the protocol of communication between speakers, and then how they modify their concepts.

3.2.1. Protocol

Interactions take place between two members of the population. When two of them are chosen to interact, they are given specific roles. One of them is designated as the teacher, while the other is the learner. The teacher chooses one of the objects of the world, and indicates its choice to the learner by pointing to the object. The learner's goal is then to perceive, categorize and name the object indicated by the teacher.

Once the object is placed in the learner's conceptual space, she[2] must categorize it. A concept C may be used to categorize an object 0 if $\mu_C\,(O) \geq 0$. The learner can thus have many concurring concepts during the categorization process. The concept C_k that results of the categorization is stochastically determined with the probability:

$$p(C_k) = \frac{\mu_{C_k}(O) \cdot U_{C_k}}{\sum\limits_i \mu_{C_i}(O) \cdot U_{C_i}}.$$

The more the object is prototypical of the category represented by the concept and the more the learner has confidence in the usefulness of the concept, the more likely is the concept to be the result of the categorization process. The last step for the learner is to name the object, and this is done with the word w_C associated with the concept.

The teacher has then to inform the learner whether she agrees with the word used to name the object. To achieve this, she just checks if one of her concepts is associated with the learner's word, and if this concept C is such that $\mu_C(O) > 0$. If she does agree, the interaction is successful. In that case, the learner refines the concept she used for the categorization in order to make the object more prototypical. She also increases her confidence in the concept (these two actions are described in the next section). But in several other scenarios the interaction fails.

The first problem that can occur is a failure on the part of the learner to categorize the object, because none of her concepts verifies $\mu_C(O) > 0$. In that case, if the teacher is able to give the learner a word for the object, then the

[2] Speakers are asexual entities. We nevertheless choose to refer to them with the pronoun *she*.

learner acquires it. This learning can take different aspects. If the learner does not know the word used by the teacher, she creates a new concept on the basis of the object, and tags it with the teacher's word. If she already knows the teacher's word, either the associated concept was one of the concurring concepts during the categorization process ($\mu_C(O) > 0$), or it was not ($\mu_C(O) = 0$). In the first case, the learner refines her concept, and in the second she expands it in order to make its characteristic function such that $\mu_C(O) > 0$. But it might be the case that the teacher is unable to name the object. When this happens, they both create a new concept, and tag it with a word that the teacher invents. When a teacher invents a new word, it is always a completely new word: no other member of the population knows it.

When the learner manages to name the object, it is still possible that the teacher disagrees with that name. This disagreement can have two different causes: either the teacher does not have any concept C tagged with the learner's word such that $\mu_C(O) > 0$, or she simply cannot categorize the object. In both cases, the learner decreases the confidence of the concept she used. But in the first case, the teacher names the object and the learner learns the teacher's word (all the different cases of learning discussed in the previous paragraph are possible here too).

We have seen that in response to their interactions, speakers modify their conceptual structure. They may learn new words, extend or refine their concepts and/or modify the degrees of confidence toward their concepts. Let us examine how these operations are done.

3.2.2. Word acquisition

Acquiring a new word happens when the student is told by the teacher a word he had never heard before. Learning a new word means creating a new concept. The speaker does not know anything about the word but that it stands for the object chosen for the interaction. The concept created is defined as follow: all the α-cuts are centered on the object (it is the prototype of the new concept). The radius of the α-cut C_{α_n} is $\frac{R_{\text{new}}}{n+1}$, where R_{new} is a parameter of the model. The initial confidence degree of a new concept is another parameter of the model, U_{new} (in the rest of this paper, R_{new} is set to one-thirtieth of the size of the conceptual spaces, and U_{new} to 0.5).

3.2.3. Concept extension

Speakers have to extend a concept when they are told that a word (which they already know) is usable for an object that is not in the scope of the concept yet. All of the α-cuts are modified. The different factors involved in the modification of C_{α_n} are the position of its center P, its radius r, the position of the object O, α_n and the concept degree of confidence U. When a member of the population is told about the association of a word she knows and an object, she may consider this object rather peripheral according to the category associated with a word. It would be surprising if a new example of a category modified radically the prototype of the category. So the closer α_n is to 1, the less C_{α_n} is modified. It would also be surprising if a speaker modified a concept that has been very useful in the past and thus in which she has a high degree of confidence. So the more U is close to 1, the more the speaker is confident in her knowledge, and the less the concept is modified.

If d is the distance between the center of C_{α_n} and the object, the new radius r' of C_{α_n} is:

$$r' = r + \frac{d-r}{2} \cdot (1-U) \cdot (1-\alpha_n)\,.$$

The center P is moved in the direction of the object in order not to generalize in the opposite direction of the object (see Figure 3a). In vectorial notation, we have:

$$P' = \frac{\beta_1 \cdot P + \beta_2 \cdot O}{\beta_1 + \beta_2}, \text{ with } \beta_1 = r' - r = \frac{d-r}{2} \cdot (1-U) \cdot (1-\alpha_n)\,,$$
$$\text{and } \beta_2 = d - \beta_1\,.$$

In addition to these modifications, there is a constraint such that the radius cannot be increased nor the center be moved in a way such that $C_{\alpha_n} \not\subset C_{\alpha_{n-1}}$.

3.2.4. *Concept refinement*

Concept refinement occurs when a speaker has to tune a concept according to the information given by the position of an object that has already been categorized by this concept. When an object is categorized by a concept, the point that represents this object belongs to some of the α-cuts of the concept, maybe all, maybe not, depending on the typicality of the object. α-Cuts are not modified in the same way when they contain the object or not. α-Cuts that do not contain the object are modified in the same way than in the case of extension of concepts. α-Cuts that do contain the object are recentered around

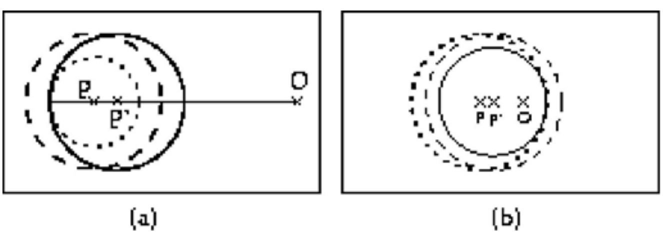

Figure 3. (a) α-Cut C_{α_n} before extension (dotted line), after modification of the radius (dashed line) and after modification of the center (plain line); (b) α-cut C_{α_n} before refinement (dotted line), after modification of the center (dashed line) and after modification of the radius (plain line).

the object. As in the case of extension, the higher the degree of confidence of a concept is, the less its α-cuts are modified. But the more the object is typical, i.e. the more the α-cuts in which it falls down have high α_n, the more it gives information to the category formation. So the higher α_n is, the more the α-cut is modified. If an α-cut C_{α_n} with center P and radius r is refined according to an object represented by the point O, its new center P' is the barycenter of the points $O$and $P$with respective weights $\alpha_n \cdot (1 - U_C)$ and $1 - \alpha_n \cdot (1 - U_C)$. The radius is then modified so that the α-cut after modification is included in what it was before: $r' = r - d_{PP'}$, where $d_{PP'}$ is the distance between the old position of the center and the new one (see Figure 3b).

3.2.5. *Modification of the degree of confidence*

A speaker increases (decreases) the degree of confidence of a concept when an object has been successfully (unsuccessfully) named by the word associated with the concept. At the same time when a speaker increases (decreases) the weight of a concept, she decreases (increases) the degree of confidence of all the concepts that were concurring in the categorization process for this object. The more the object is typical, the more the degree of confidence is modified. If a speaker has a high (low) degree of confidence in a concept, it will not decrease (increase) remarkably after one successful (failed) interaction.
When the degree of confidence U is increased given an object O it becomes U' :

$$U' = U + \min(U, (1 - U)) \cdot \mu(O) \cdot \delta,$$

and when it is decreased:

$$U' = U - \min(U, (1 - U)) \cdot \mu(O) \cdot \delta,$$

where δ is a parameter of the model. In all the following simulations, δ is set to 0.2.

If a speaker has a very low degree of confidence for a concept (under $U_{\min}$, a parameter of the model set to 0.1), she forgets the concept (and the associated word).

3.3. *Social Relations*

Our population is not an unstructured set of speakers. Not everybody can be the teacher of anybody. At each instant, the population is composed of two generations, an old one and a young one. Every T_{gen} interactions, the old generation disappears, the young generation becomes old, and a new young generation of speakers is created (T_{gen} is set to 15,000 for the rest of the paper). A newborn speaker does not have any knowledge, i.e. any concept. It then would not make any sense to have such a speaker as a teacher. The teacher is thus always from the old generation. The learner may be from one generation or the other. As a consequence, transmission of knowledge occurs both vertically and horizontally. In the simulations presented here, each generation is composed of 30 speakers.

3.4. Environment

The population's environment consists of the set of objects they can choose from for their interactions. The only thing they can do with these objects is to perceive them. As we explained in Section 3.1.1, perception of an object consists in determining its coordinates in the conceptual space. We assume that all speakers have the same perceptual apparatus. So a given object has the same coordinates in every speaker's conceptual space. Objects are thus only defined by their coordinates in speakers' conceptual spaces.

As in the world in which we live in, the environment in the simulation we report here is not a simple pack of objects. It is on the contrary structured. Structured environments have been shown to increase communication (Smith, 2003). The initial conditions of all the simulations are the following: 90 objects are distributed in nine clusters. Figure 4 shows the repartition of the clusters in speakers' conceptual spaces. The size of the clusters is R_{new} (we suppose that speakers have phylogenetically evolved in such a way that they create new concepts with a size that matches their environment's regularities).

This world is not static: both the positions of the clusters and the positions of the objects within the clusters change. The evolution of the positions of the cluster is one of the parameters that will vary in the following simulations, and

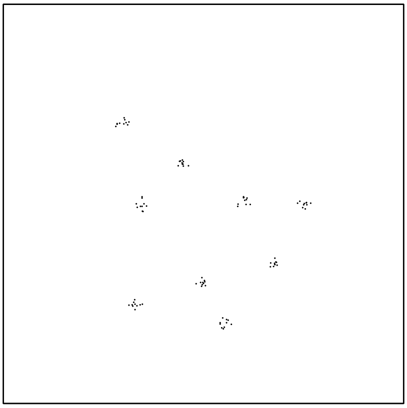

Figure 4. Initial positions of the clusters of objects as the speakers perceive them through their conceptual space.

will be described when necessary. Within each clusters objects are changed every R_{obj} interactions. For the rest of the paper, R_{obj} is set to 500.

4. SIMULATIONS

4.1. Measurements

In order to describe the processes going on in the population, we need to define some informative quantities. The first that will be of interest is *success*. Success is simply the ratio of successful interactions over a fixed number of interactions (1000 for all the simulations).

Coherence and *stability* are also of important interest. These two measurements are computed when a generation dies. They are both defined with reference to speakers' similarity. The similarity $\mathrm{Sim}_{1,2}$ between two speakers S_1 and S_2, is computed as follow: for each word, we compute the volume of the intersection of the associated fuzzy vectors of the speakers (this intersection is null if one of the speakers does not know the word). The sum over all the words is the volume $V_\cap$ of the intersection of their conceptual spaces. Let V_1 and V_2 be the volume of the conceptual space of S_1 and S_2, respectively (i.e. the sum of the volume of the fuzzy vectors). $V_\cap \big/ V_1$ (respectively, $V_\cap \big/ V_2$) is that part of the knowledge of S_1 (respectively, S_2) also known by S_2 (respectively, S_1). We define the similarity $\mathrm{Sim}_{1,2}$ between S_1 and S_2 as $\mathrm{Sim}_{1,2} = \frac{1}{2}\left(\frac{V_\cap}{V_1} + \frac{V_\cap}{V_2}\right)$.

When a generation dies, for each of its speakers S_i, we measure the mean similarity Sim_i^0 with all the speakers of its generation and the mean similarity Sim_i^{-1} with all the speakers of the previous generation (i.e. the generation that died T_{gen} before and that has transmitted its knowledge vertically to the dying generation). The mean over all the speakers of the dying generation of Sim_i^0 gives the coherence of the population, and the mean over all the speakers of Sim_i^{-1} gives the stability with respect to the previous generation.

4.2. Simulation 1, Emergence of a Lexicon

In this first simulation, the positions of clusters do not vary. It is aimed to present the general dynamics of the model and to give an answer to the following problem: we said that the young generation does not provide teachers since when speakers arrive in the population they are without any knowledge. But what about the first generation? As it is the first one, there is no old generation from which to obtain knowledge. This simulation shows that if we make an exception to our rule for the first generation and permit teachers to be from

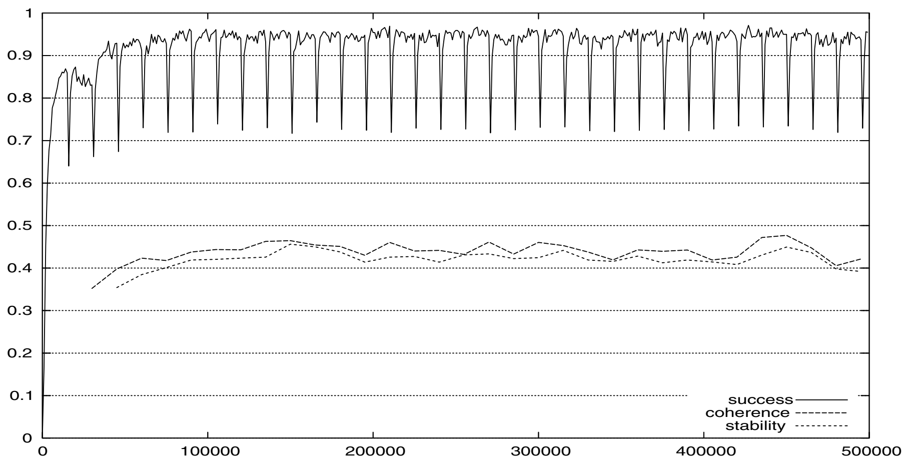

Figure 5. Plots during 500,000 interactions of the success, the coherence and the stability of a population of 30 speakers per generation in a stable environment.

the young generation (the only one at this point), a lexicon emerges from the interaction.

Figure 5 shows the evolution of the success, coherence and stability for 500,000 interactions. Several remarks can be made: after 100,000 interactions the plot of success oscillates around 0.95, with regular abrupt downfalls. These downfalls occur indeed every 15,000 interactions and correspond to generation replacement: as explained in Section 3.3, newborn speakers do not have any knowledge and thus fail to communicate during their first interactions. But they learn very quickly, and subsequent interactions are generally successful. Coherence and stability have similar shape, oscillating around 0.45, except at the beginning of the simulation, before success stabilizes, indicating that speakers always differ in their conceptual structure, and thus explaining why success never reach 1.

If we turn to the lexicon used by the population, we learn (see Figure 6) that after an adjustment period, it oscillates between 40 and 60 words. Each word stands on average for 9.5 objects, all from the same clusters: speakers use words that refer to clusters of objects. Given that there are nine clusters of objects in speakers' environment, such a lexicon would imply a large amount of synonymy (more than five words on average per cluster). But this view is not very precise, and looking at each speaker's private lexicon rather than at the pool of lexical items is more informative: the last generation of speakers only know 13.03 words out of the 49 spread in the population at this time, and while nine words of the lexicon were created before the 500th interaction, the 40 others were created after the 440,000th one. Moreover, every speaker knows the nine old base words with a high degree of confidence in the associated

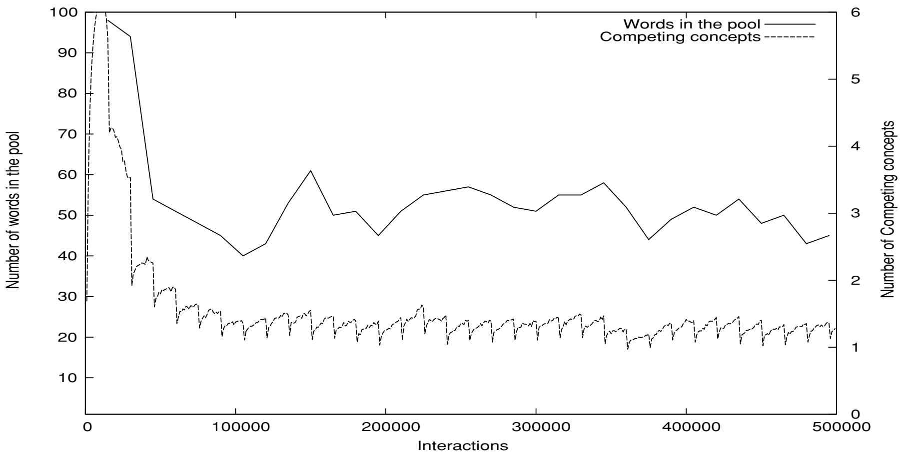

Figure 6. Plots during 500,000 interactions of the number of words in the pool and the number of competing concepts during the categorization process in a population of 30 speakers per generation in a stable environment.

concept (i.e. in the meaning of the word), while degrees of confidence are always less than 0.5, their initial value, for the other words. The population uses in fact one word per cluster: speakers have on average between 1 and 1.5 different ways of categorizing the object of interactions (see Figure 6). 'Satellite' words are permanently created. They stay in the population for a few generations (a word created at the 440,000th interaction and still present at the 500,000th has been used for six generations), and then disappear. These words are not very widespread in the population since each speaker only knows 13.03 words including the nine base words.

One of the goals of this simulation was to investigate whether in our model the population is able to develop a lexicon from scratch. When looking at the results, no doubts can be cast on this. This 'phylogenic' acquisition of a lexicon is similar but nevertheless distinct from the ontogenic one which occurs when a new generation arrives in the population. Whereas a new generation acquires the conceptual structure and the associated lexicon very quickly, emergence of shared conceptual structure and lexicon is a longer process, lasting over several generations. Our model relies on the strength of cultural transmission of acquired knowledge from one generation to the following one.

4.3. Dynamics of the Lexicon in a Changing Environment

Contrary to other aspects of language such as phonology or syntax that are constrained only by speakers' physiological or cognitive structures, the lexicon is constrained by the environment it refers to through mental representations. Consequently, as the environment changes, speakers must modify their

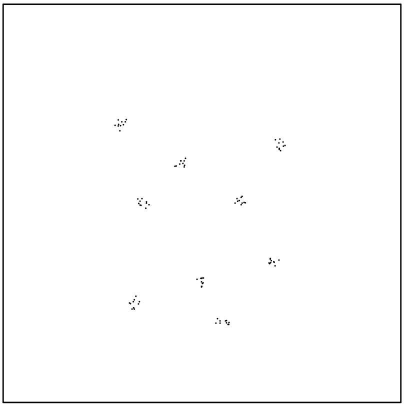

Figure 7. Final positions of the clusters after the change.

conceptual structures and thus their lexicon. This is the process to which we will now turn. As mentioned in Section 3.4, the environmental evolutions that we will consider are changes in the position of clusters. In order to keep things tractable, the position of only one cluster will be changed here. The parameter we will vary is the speed of the transition from the initial to the final state which is represented in Figure 7.

4.3.1. Simulation 2

In this simulation, the population is placed in an environment that will change from the initial to final conditions in 10,000 interactions, from the 100,000th to the 110,000th. Figure 8 shows the evolution of the success and the transmitted knowledge for 300,000 interactions.

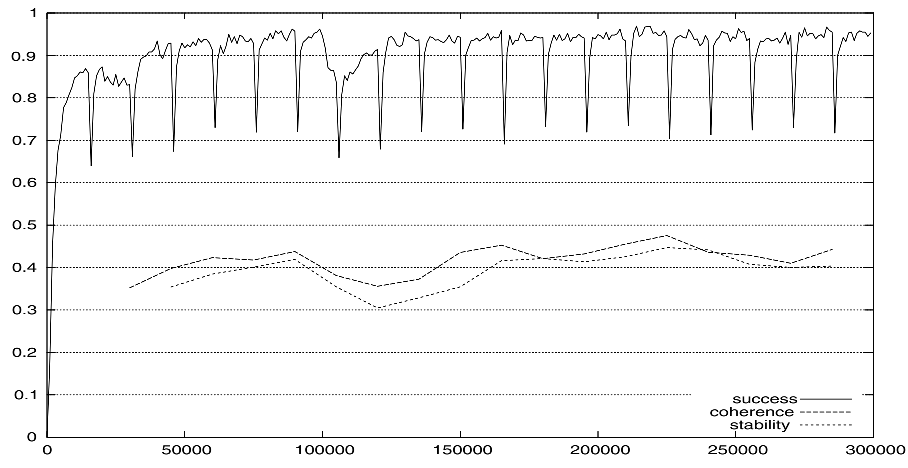

Figure 8. Plots during 300,000 interactions of the success, the coherence and the stability of a population of 30 speakers per generation in an environment changing in 10,000 interactions.

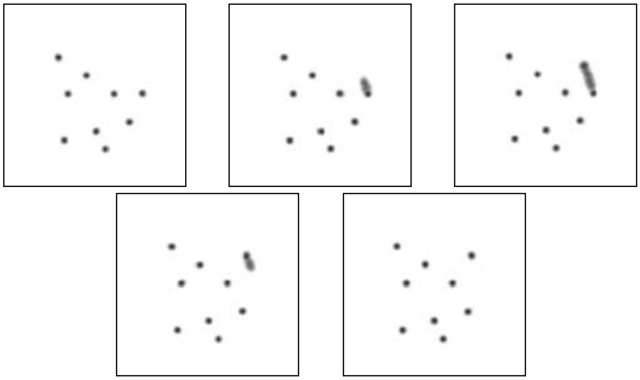

Figure 9. Mean conceptual space of the generation that died at the 90,000th, 105,000th, 120,000th, 135,000th and 150,000th interactions.

In these conditions success is perturbed during the cluster position transition but recovers its prior level just after the transition. Coherence drops from the 105,000th interaction to the 135,000th, as does stability from the 105,000th to the 150,000th. Coherence is low for the three generations that experienced the transition.

Figure 9 presents the mean conceptual space of the generations that died at the 90,000th, 105,000th, 120,000th, 135,000th and 150,000th interactions.

Even if the transition is shorter than a generation's lifetime, three of them have experienced it, and this perception has marked their conceptual structure. These marks of transition indicate the transition long after it ends, and much longer than the communicative success does. Because of these traces of an environment that does not exist anymore, speakers cannot develop a conceptual structure similar to their parent's, and this causes the stability to drop.

The lexicon of the population is again composed of nine basic words shared by all the speakers, and a set of satellite words. The basic word used for the changed cluster at the end of the simulation is created between the 108,000th and 108,500th interactions. As long as the transition is going on the population invents new words, and lexicalizes one of them only after the transition it is over. Figure 10 shows the average number of competing concepts during categorization and the number of word in the pool. It indicates that this lexical innovation period is also characterized by a higher synonymy level, which is the cause of the low coherence.

4.3.2. Simulation 3

The next simulation is exactly identical to the previous one, except that the transition between the initial and final position of the cluster is not as rapid. We still seek semantic change, i.e. changes of the representation associated with a

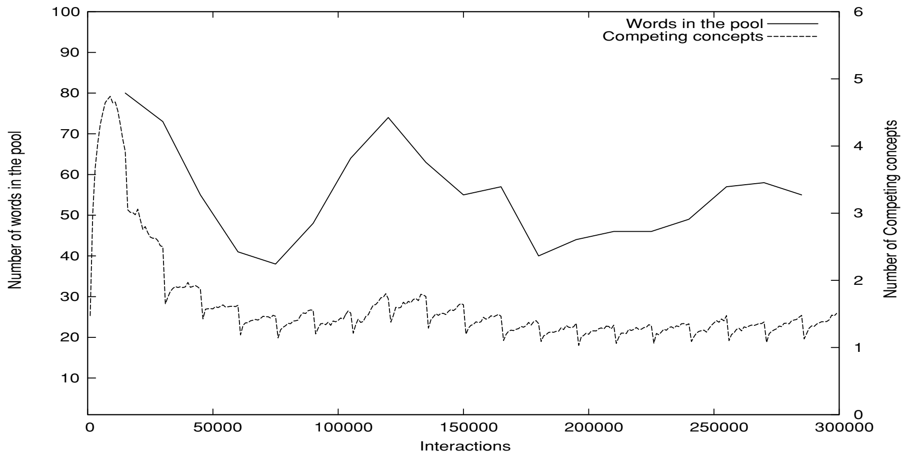

Figure 10. Plots during 300,000 interactions of the number of words in the pool and the number of competing concepts during the categorization process in a population of 30 speakers per generation in an environment changing in 10,000 interactions.

word, and neither word loose nor lexical innovation as observed in the previous simulation fall into this category. The hypothesis behind this simulation is that if the transition is stretched over several generations, semantic change may occur. Figure 11 shows the evolution of the success and the knowledge transmission for 500,000 interactions with a transition occurring between the 100,000th and the 200,000th interactions.

Success and stability are both lower than their normal level during transition. Coherence is less affected.

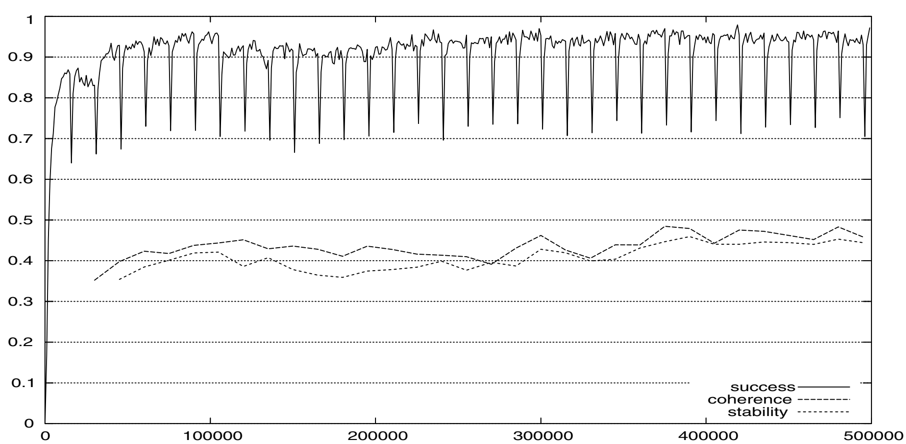

Figure 11. Plots during 500,000 interactions of the success, the coherence and the stability of a population of 30 speakers per generation in an environment changing in 100,000 interactions.

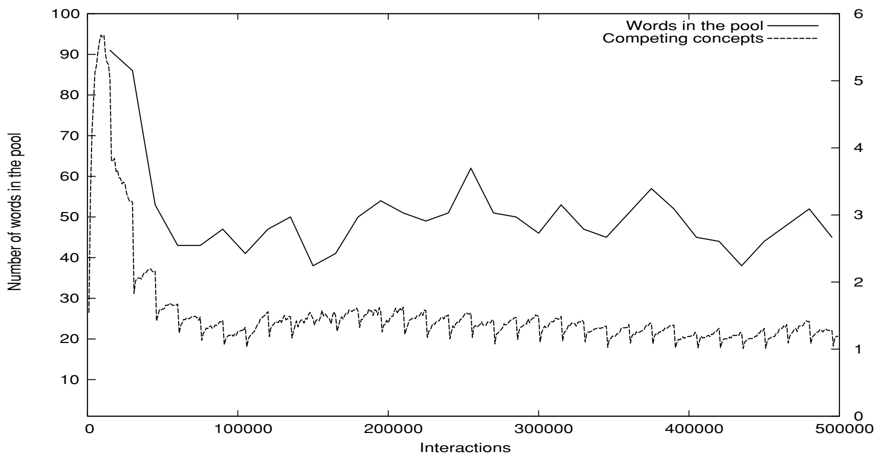

Figure 12. Plots during 500,000 interactions of the number of words in the pool and the number of competing concepts during the categorization process in a population of 30 speakers per generation in an environment changing in 100,000 interactions.

The lexicon at the end of the simulation has a similar pattern than in the previous: nine basic words are shared by all the speakers. Figure 12 is a plot of the synonymy in the population. Again the transition induces more synonymy in the lexicon. The word for the changed cluster appears in the population between the 173,000th and 173,500th interaction, the population opting again for lexical innovation rather than changing the meaning of the word used for the cluster before the transition. Nevertheless, at the 173,500th interaction, the position of the cluster was not the final one, and thus representations associated to the word at this moment were different from these associated to it after the transition. This is a case of semantic change.

4.3.3. Simulation 4

This last simulation with simple environmental evolution is similar to the two previous in all respects, expect for the number of interactions needed for the transition, which is now set to 500,000. Figure 13 shows the evolution of the success and the transmitted knowledge for 700,000 interactions with a transition occurring between the 100,000th and the 600,000th interactions.

Success, coherence and similarity are not affected by the transition. The reason is that the change is so gradual that speakers are not aware of it. Figure 14 present the mean conceptual space of generations that died at the 105,000th, 300,000th and 600,000th interactions. Contrary to Figure 9, no traces of environmental changes are observed.

If we turn to the lexicon of the population at the end of the simulation, the situation differs from the previous simulation. There are still nine basic words

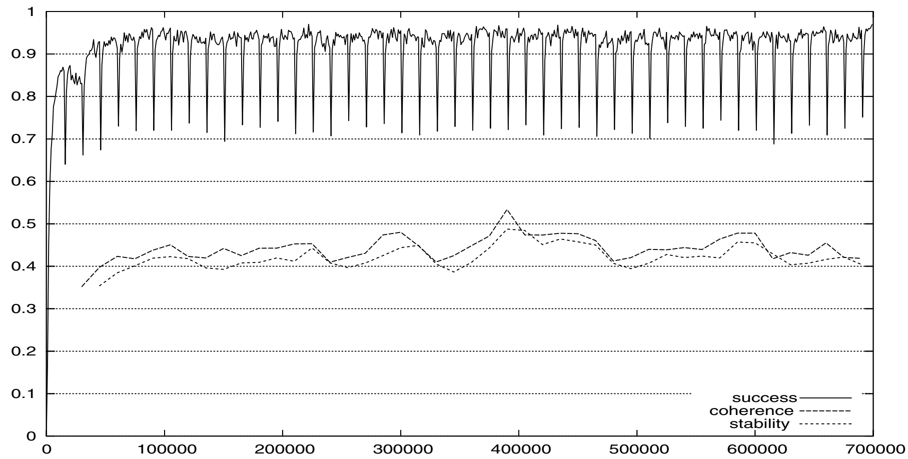

Figure 13. Plots during 700,000 interactions of the success, the coherence and the stability of a population of 30 speakers per generation in an environment changing in 500,000 interactions.

plus satellite words, but the basic word used for the changed cluster is created before the 500th interaction, i.e. at the very beginning of the simulation, simultaneously with the other basic words: the concepts associated with it in the successive generations represent the different stages of the evolution of the cluster, evolving with it. As Figure 15 indicates, synonymy is not affected by this transition.

5. DISCUSSION

5.1. The Model Itself

Evolutionary linguistics, i.e. computers simulations for the evolution of language, is an approach that has exponentially grown in the last few years. It uses the power of computers to allow us to build virtual labs in which we can test hypothesis that would have been only speculation otherwise.

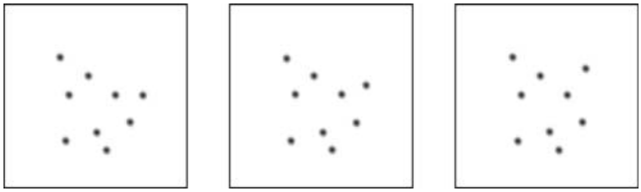

Figure 14. Mean conceptual space of the generation that died at the 105,000th, 300,000th and 600,000th interactions.

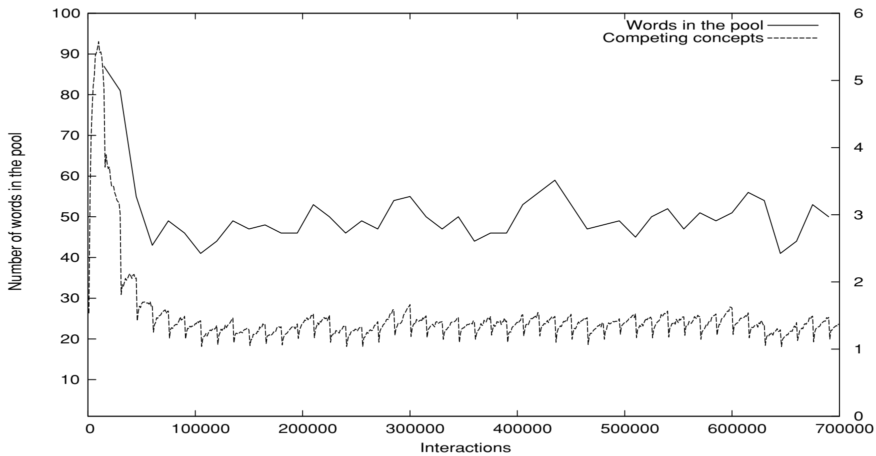

Figure 15. Plots during 700,000 interactions of the number of words in the pool and the number of competing concepts during the categorization process in a population of 30 speakers per generation in an environment changing in 500,000 interactions.

Our model follows along the same lines as many others related models that include some semantics (Steels, 1998; Hashimoto, 1998; Hurford and Kirby, 2001; Smith, 2003; Vogt, 2003). However, most of these models suffer from a double grave vice already mentioned by Smith (2003) and Vogt (2003): communication acts upon a predefined semantics and meanings are explicitly transmitted. However, as explained in Section 2, not only meaning is grounded and then not predefined, but it is also private to speakers and cannot then be explicitly transmitted without some kind of mind reading or telepathy. This telepathical prerequisite is a hypothesis put in the models that obviously contradicts reality. Moreover, as noted by Smith (2003), if both the meaning and the signal are explicitly transferred in communication, then the signal does not convey the meaning anymore, and thus becomes useless.

According to Smith (2003), in order to obtain a communication without explicit meaning transfer

> there must be at least three separate levels of representation in the model: the external, public world, a private, agent-specific internal semantic representation, and a set of signals, which can again be publicly observed. The mapping between the public and the private sections of the model must be specific to each agent and unobservable to the others [. . .].

Our model meets these requirements, and to our knowledge, only few models (Steels, 1998; Smith, 2003; Vogt, 2003) do, exhibiting as in our case a co-evolution of lexicon and conceptual structure.

However, all these models build private meanings by successive division of the meaning space, leading to concepts that represent clear-cut classical categories, without any possible way of exhibiting prototype effects. This drawback is not present in our model in which speakers build the semantics of their lexicon in a Roschian way.

We have here a model that both avoids the mind reading problem[3] found in most of models and represents categories in a much more natural way than the models discussed above.

5.2. *The Simulations*

The results from the simulations we ran with our model show that populations can build a lexicon from scratch and can transmit it from generation to generation. This lexicon is efficient and permits successful communicative interactions between the members of the population.

In all the simulations, the lexicon that is developed is composed of two sets of words: basic words, shared by all the speakers and transmitted through generations, and satellite words, used only by a part of the population and that have a limited lifetime in the lexicon. Together, all these words constitute a lexical pool in which new speakers select their vocabulary. Given that the concepts which are developed by speakers match clusters of objects, and given the number of words in the pool (typically 50) and the number of clusters (9), there is a considerable amount of synonymy in the pool, and thus considerable competition for the selection by the speakers.

Several factors can explain how this selection operates. First, it is worth noting that speakers select a limited number of words out of the pool. This is due to the cognitive architecture of the speakers, and more specifically to the *winner-takes-all* strategy of rewarding successful concepts. When an agent has many competing concepts for the categorization of an object, the winner, if the communication is successful, has its degree of confidence increased, while other competing concepts have their degree of confidence decreased. The winner is then more likely to win the next categorization, decreasing again the degree of confidence of others competitors, which may finally be forgotten by the speaker. Synonymy is thus rejected by the members of the population, who do not select all the words of the pool. A similar result has been obtained by Hurford (2003) who argued that synonymy is rare because of production constraints rather than on comprehension constraints.

[3] Our model avoids mind reading in the sense that it evacuates explicit meaning transfer. But in fact, it faces the mind reading problem in the sense of Qine (1960): we assume that the learner automatically identifies the referent indicated by the teacher, while in real world this ambiguity about the referent is in fact present in many cases.

Another factor that explains the selection of lexical items by speakers is their frequency. As soon as the set of basic words is established, since all speakers know them they are used much more frequently than satellite words with more restricted diffusions. This frequency bias toward basic words makes them much more likely to be learnt.

As mentioned in Section 4.3, lexicon is not only shaped by structural, cognitive or even physiological constraints as phonology or syntax are, but also by the environment it refers to. As simulations 2 and 3 have shown, when the environment is changing, it may be the case that words in the pool are used by speakers with meanings that no longer represent the world appropriately. This fitness constraint can be strong enough to influence speakers so that they do not select those words, with the consequences that the basic vocabulary is not entirely transmitted across generations and that synonymy increases, overriding then both the cognitive constraint against synonymy and the frequency bias.

However, all these factors are in fact competing during selection, and simulation 3 and 4 give insights on this factor competition. In simulation 3, we saw that the word for the moved cluster is introduced in the lexicon at ¾ of the trajectory of the cluster. This means that during the last quarter of the trajectory, even if the meaning of this word never fits perfectly its referents that are still changing, it is still selected from the pool by the learners. The meaning they associate to this word is then different from their parents', adapting their conceptual structure to their environment. The word experiences then a semantic change.

In simulation 4, the change is so slow that the word that refers to the cluster always fits its referents quite well. The pressure of the fitness constraint is then very weak, and the frequency bias makes the learner select the basic word. They nevertheless build a meaning for it slightly different from their parents', the word experiencing then a semantic change too.

6. CONCLUSION

It seems that the universe is such that the complex entities which it harbors cannot be stable and have to evolve. These evolutionary processes are fascinating when we look at complex systems such as life, language or culture. It is amazing to see that even if these processes are definitely distinct, robust parallels can be drawn between them.

In this paper, using Mufwene's (2001) metaphor *language as species,* we have shown that the very cultural process of language evolution is affected by the major constraint in natural selection, viz., fitness to the environment. In the case of language, it is just one constraint among others, and all compete to drive language evolution.

The model we developed solves the explicit meaning transfer problem, speaker's concepts being completely private. Moreover their concepts have a structure that takes into account the Roschian insights about categorization. But this model is nevertheless far from perfect since it lacks important aspects of language such as polysemy or compositionality. It has its own features that now belong to the models' feature pool, and we hope that evolution will play its role and that future models will select the good ones.

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Evolutionary epistemology and the origin and evolution of language: Taking symbiogenesis seriously

Nathalie Gontier

Research Assistant of the Research Foundation—Flanders (F.W.O.–Vlaanderen)
Centre for Logic and Philosophy of Science,
Vrije Universiteit Brussel, Brussels, Belgium
nathalie.gontier@vub.ac.be

Abstract

Symbiogenesis is a form of horizontal evolution that occurred 2 billion years ago, with the evolution of eukaryotic cells. It will be argued that, just as we can develop universal selection theories based upon a general account of natural selection, we can also develop a universal symbiogenetic principle that can serve as a general framework to study the origin and evolution of language. (1) Horizontal evolution will be compared with and distinguished from vertical evolution. (2) Different examples of intra- and interspecific horizontal evolution will be given to show that horizontal evolution is quantitatively and qualitatively the most commonly occurring form of evolution throughout the history of life. (3) Finally, three examples are given of how a universal symbiogenesis principle can be implemented in the study of language origins and evolution, more specifically within: (a) the study of language variation, (b) language genes and (c) conceptual blending.

1. INTRODUCTION

The universal selectionist models (Campbell, 1959, 1960, 1974, 1977, 1987; Cziko, 1995; Hull et al., 2001), universal Darwinism (Dawkins, 1983) or philosophical Darwinism (Munz, 2001) developed by evolutionary epistemologists, are all based upon the evolution of genes by natural selection.

These theories, although they are very useful to study the evolution of animals, are not adequate to study phenomena such as language or culture. Language and culture do not follow rigid evolutionary schemes analogous to the evolution of genes, rather they have their own peculiarities that need to be studied in their own right.

To begin with, it is difficult to pinpoint one unit and one level of selection, because languages and cultures can take on many forms. Languages are the result of many different elements that are combined: speech, thinking, grammar,

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semantics, sensory-motor actions, memory, (co-verbal) gesturing, language rules and language games. And in the case of culture, there is the individual that adheres to different (sometimes contradictory) views, that are categorized by a brain; there is the interaction with significant others within a community; and there are cultural artefacts that need to be taken into consideration.

These peculiarities, however, can also be formalized, analogous to different evolutionary theories, one of the most important being symbiogenesis. Ruse (1985) already pointed out that we have to take Darwin seriously, meaning, amongst other things, that our cognitive capacities such as language and culture need to be studied as a product of Darwinian evolution. However, here it will be argued that we should also take symbiogenesis seriously.

Symbiogenesis is a form of horizontal evolution and it will be argued that horizontal evolution is quantitatively and qualitatively the most commonly occurring form of evolution throughout life's history. Evolution by natural selection is a form of evolution that, during and within the evolution of life, only plays a minor role within the evolution of animals.

Given this minor role that natural selection plays within evolution, it is too short-sighted to only develop general normative frameworks based upon Neo-Darwinian theory to study all of life's phenomena. First of all, it is bad science because it neglects all other evolutionary theories that provide adequate and scientific explanations regarding certain phenomena. Secondly, this unnecessarily narrows down the options of linguists and anthropologists, leading to today widely defended views that naturalistic approaches cannot adequately address culture or language, because the, on biology-based, theories of language and culture that are introduced by evolutionary epistemologists, supposedly cannot account for a diversity of research topics within language and culture (e.g. recursivity, creativity, religion, arbitrary rituals and so on).

Here a much more optimistic view is given. The above-mentioned criticisms should not be regarded as negative, but as positive. For where natural selection, or where EE(M)-models (Gontier, this volume) based upon natural selection fail, it is not necessary to abandon a naturalistic approach altogether. We can turn to other evolutionary frameworks, such as symbiogenesis, that *can* deal with, and formalize, these phenomena.

First, horizontal evolution is distinguished from vertical evolution. Secondly, it is shown how both evolutionary concepts are being applied within the study of language. Thirdly, symbiogenesis is universalized and it is shown how we can apply this normative framework to the study of phenomena such as language variation and evolution, language genes and conceptual blending.

2. HORIZONTAL VERSUS VERTICAL EVOLUTION

Contrary to received wisdom, horizontal evolution processes occur quantitatively and qualitatively more often than vertical evolutionary processes. We will start off by defining our concepts.

2.1. Vertical Evolution[1]

Vertical evolution is evolution as we have all learned it at school: it is evolution by natural selection. Neo-Darwinian theory (Ayala, 1978; Mayr, 1978, 1983; Dawkins, 1983, 1984, 2000; Dennett, 1995; Gould, 1980, 1982, 1991; Maynard Smith, 1993) adheres to the view that *only* speciation leads to the evolution of new species.

To give only one standard example of how this speciation takes place, let us look into 'allopatric speciation by peripheric isolation'. This catchy phrase refers to the following scenario. A subgroup of a population of a certain species gets isolated from the main group (by the eruption of a volcano that burns the ground, leading to the subgroup not crossing this land even if the ground is cooled of, because they do not recognize it as their territory or niche; or by another geographical barrier, such as water because of floods). Given that this isolation takes a very long time, it is possible that one or several random mutations occur and spread within the subgroup. Again, given enough time, should the subgroup and the main group meet again, it could be that these different groups cannot fertilize each other or cannot produce fertile offspring, while members of the same group can produce fertile offspring. If the latter is the case, then we have a new species. Actual examples of allopatric speciation by peripheric isolation have only been reported a couple of times.

Processes like allopatric speciation by peripheric isolation, together with other such processes (for example species-mate-recognition patterns,[2] see for instance Schwartz, 1999) lead, randomly, to the evolution of new species by speciation: new species evolve out of and split off from older, sometimes still existing species. Hence a family tree with a branching pattern is regarded as

[1] What is being argued here might seem trivial but it is not. Most non-biologically schooled scholars think that evolutionary biology is simple, it is not. Evolution in some cultures today is part of a way of life, of a philosophical understanding of the world, leading to the idea that everybody knows what evolution is about and that evolution is easily comprehensible. Again, it is not.

[2] Recognizing that someone belongs to the same species and that this organism is of the opposite sex and hence a potential mate.

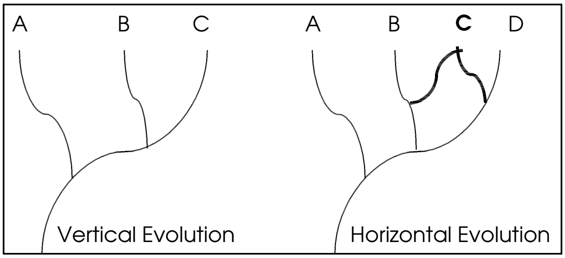

Figure 1. Vertical evolution follows a typical branching pattern: different lineages cannot cross, nor blend, while in the case of horizontal evolution, different lineages can cross.

the most suitable way of iconizing vertical evolution (Figure 1).[3] This is what Darwin talked about: species are not static entities; they evolve out of each other by speciation.

Neo-Darwinian theory, more specifically Ernst Mayr, later on introduced the term allopatric speciation by peripheric isolation. Neo-Darwinian theory also added Mendelian hereditary laws, genes, mutations and mathematics to this speciation concept (Gontier, 2004) to answer the following question: what happens during vertical evolution?

The answer to that question is: *existing or new characteristics are retained by inheritance (genetically) and spread throughout the population across time, from generation to generation, sometimes leading to speciation or extinction*.

Actually, today, we would not say that it is characteristics, but genes that are retained and inherited by recombination. This is because we do not quite know how genes encode for characteristics (all they seem to encode for are amino acids that form proteins that form tissue). The point is, however, that it is presumed that genes, in a yet to be explained manner, encode for certain characteristics of an animal, and that these genes need to be inherited from one generation to the next, in a vertical fashion.

[3] Gould (1984, 1991) already emphasized from within Neodarwinian theory that this iconicity however is not suitable to explain evolution, because vertical evolution implies that there is one common point of departure (and beginning) and from there, the tree diversifies, the idea being that the maximal diversification lies at the end of the tree, comparable with a Christmas tree turned upside down. However, he showed that the maximal diversity lies not at the end of the tree of life, but somewhere in the middle. After the Cambrian explosion, there was a decimation of most phylogenetic branches. Only the few phylogenetic branches that did survive this decimation show an enormous diversification within these different phylogenies. There are few branches (body designs), but lots of twigs on these branches (species with a certain body plan), a process that he characterizes as early experimentation and later standardization.

Again, we need to be more cautious with our definition: vertical evolution at the animal level implies that two members of the same species, of the opposite sexes, mate, and that during this mating process, one sex cell from each parent merges with the other to form a fertilized cell, from whereupon an embryo develops. So half of the genes of the mother and half of the genes of the father are recombined in a fertilized egg cell (as we shall see under Section 2.2.1, this is not totally correct either).

Vertical here has two meanings: (1) half of the genes of the parents are passed on to the next generation; (2) only those characteristics that are somehow genetically encoded for in the individual *can* possibly get passed on to the next generation. If they are passed on, these genes and hence the characteristics are retained in the next generation.

The more a gene is retained within the next generation through time, because the carrier is fit and hence able to reproduce, the more it is spread throughout the population in general and the more it can get fixed within a species. P1 gives the gene to offspring F1,[4] who mates with x, and passes the gene on to their offspring and these in turn have offspring with y and z and pass the gene on to their offspring. Hence an existing gene will spread throughout a population, which does not necessarily lead to the evolution (by speciation) of a new species.

Sometimes a gene undergoes a random mutation. If this mutated gene is to be passed on to the next generation, a few conditions are given by Neo-Darwinian theory. The mutation *can* (possibly, not necessarily) only be passed on to the next generation, if the mutation occurs in one of the sex cells and if this sex cell (a sperm or an egg cell) is used during reproduction to form a zygote.

This means that the organism with the mutation has to be able to reproduce itself. It can only reproduce itself if it is able to survive long enough to find a mate, and it can only find a mate if the two parents recognize each other as potential mates. Hence we find the introduction of concepts such as adaptation (to the environment in order to survive long enough) and fitness (to be able to reproduce itself at a maximal rate), concepts that all too often are intertwined.

So Neo-Darwinian theory basically studies two processes: (1) the recombination of genetic material at the level of the sex cells (meiotic recombination); and (2) the possible occurrence of genetic mutations at the level of these sex cells, because if advantageous to the individual and passed on to the next generation, the mutations possibly lead to new species (Gontier, 2004).

Vertical evolution though, is primarily a zoological concept that can only be applied to a certain degree to animal evolution. Most Neo-Darwinians are zoologists as well.

[4] P (parentes) is the symbol for parents and F (filius) is the symbol for offspring. The number after the symbol indicates the number of generations.

2.2. Horizontal Evolution

Horizontal evolution (Figure 1) is evolution through symbiogenesis (Section 2.2.1) or hybridization (Section 2.2.2) but it can also occur at the inter- and intraspecific level of animal evolution (Section 2.2.3). Two general definitions can be given:

(1) *Horizontal evolution is the coming together and merging of existing and independently evolved evolutionary lineages* (we will return to this definition under Sections 2.2.1–2.2.3).
(2) *Horizontal evolution happens when existing characteristics are retained and spread out geographically within members of a population* (*and across generations through time*).

The second general definition of what horizontal evolution is about resembles the definition of vertical evolution, but there is a difference: only *existing* characteristics are retained and spread throughout a population. Neo-Darwinians do not explain this phenomenon of horizontal evolution as a form of evolution, rather they regard the process of passing on already existing genes as part of *variation*. The more variation, the less genes are held in common within members of the same species; the less variation, the more genes are 'fixed' within a population and hence are regarded as (linked to) typical traits of that population.

As mentioned above, the Modern Synthesis focuses on two steps: the sex cells, where genes possibly are passed on from one generation to the next, and possible random mutations that occur within these genes. Hence the popular idea put forward by Neo-Darwinians that animals pass on their *genes* from one generation to the next (Gontier, 2004).

This is not true: animals do not pass on their genes from one generation to the next, they pass on their *sex cells* (that contain genes) from one generation to the next, and here a horizontal element is involved: namely, two members of the same species, of the opposite sexes, mate and if all goes well a sperm cell penetrates an egg cell, resulting in the formation of a cell with diploid chromosomes.

> "Zoologists, those who professionally study animals, have imposed a distinct concept of species, which they call the 'biological species concept'. Coyotes and dogs in nature do not mate to produce fully fertile offspring. They are 'reproductively isolated'. The *zoological definition of species refers to organisms that can hybridize*~~tha~~t can mate and produce fertile offspring. Thus organisms that interbreed (like people, or like bulls and cows) belong to the same species. Botanists, who study plants, also find this definition useful (Margulis and Sagan, 2002: 4–5, my emphasis)."

There is more to it than a mere definition process. This crucial horizontal step is taken for granted and even ignored by Neo-Darwinian theory, because of their focus on genes. Every mating process, however, is a crucial horizontal (temporary merging) process of the parents, and every fertilization is a permanent merging and recombining of different cells that contain (mostly already existing) genes.

Since it mostly only involves the passing on or recombining of existing genes, I prefer to call this a form of horizontal evolution contrary to regarding this as part of the process of individual variation that occurs because of vertical genetic recombinations without there actually being vertical evolution (because no species evolves or goes extinct). Vertical evolution carries connotations of speciation, mutations (the introduction of new genetic material) and branching, which leads to the idea that all animals that belong to the same species, carry the same genes and that these genes are the essential characteristics of that species.

Horizontal evolution emphasizes the coming together and spreading of already existing genetic material and involves a process worth studying on its own. Only *prokaryotes* (bacteria, viruses) are able to pass on their genes, immediately and directly, within one generation or from one generation to the next. Bacteria, who happen to bump into each other, can exchange and donate genetic material: they form a bridge (literally, made from proteins) and exchange genetic material in a direct way. A process that can be understood by the following analogy:

> Imagine that in a coffee house you brush up against a guy with green hair. In so doing, you acquire that part of his genetic endowment, along with perhaps a few more novel items. Not only can you now transmit the gene for green hair to your children, but you yourself leave the coffee shop with green hair. Bacteria indulge in this sort of casual, quick gene acquisition all the time. Bathing, they release their genes into the surrounding liquid. If the standard definition of species, a group of organisms that interbreed only among themselves, is applied to bacteria, then all bacteria belong worldwide to a single species. (Margulis and Sagan, 2000: 93)

In contrast, all *eukaryotic* organisms (protists, plants, animals and fungi) pass on their sex cells (with genetic material) from one generation to the next.

2.2.1. Horizontal evolution by symbiogenesis

> Although Darwin entitled his magnum opus *On the Origin of Species*, the appearance of new species is scarcely even discussed in his book. Symbiosis [. . .] is crucial to an understanding of evolutionary novelty and the origin of species. Indeed, I believe the idea of species itself requires

> symbiosis. Bacteria do not have species. No species existed before bacteria merged to form larger cells including ancestors to both plants and animals. [. . .] [L]ong-standing symbiosis led first to the evolution of complex cells with nuclei and from there on to other organisms such as fungi, plants, and animals. (Margulis, 1999: 8)

As Margulis (1999; Margulis and Sagan, 2000, 2002) shows, all life can be divided into organisms with two basic cell types: prokaryotic organisms and eukaryotic organisms. Prokaryotes are all (Archae)bacteria (the first kingdom), quantitatively the most common form of life. Typical of these bacteria is the fact that they carry genetic material in their cells and that these genes encode for the proteins present in these cells. However, this genetic material is not organized on chromosomes, nor is it encapsulated within a nucleus. As said, these bacteria can exchange genetic material freely in a horizontal fashion.

Eukaryotes are all organisms that are part of the other four kingdoms of life: protists, animals, plants and fungi (mushrooms and yeast). The cells that make up these eukaryotic organisms, all contain genetic material that is organized on chromosomes, and encapsulated in a protecting nucleus. Animals, plants and fungi cells, beside their nucleus, also contain organelles, little bodies in the cell that are enclosed by their own membrane, and contain their own genetic material. What is interesting about this genetic material is that, when compared with the genetic material from the nucleus, it shows little to no resemblance to it. However, when the genetic material that is present in all organelles of eukaryotic cells is compared with the genetic material of today's independently existing bacteria (that is, prokaryotes) they show a very high resemblance, so high, that we have to conclude that the organelles that are part of all eukaryotic cells, used to be bacteria that lived independently. Somehow, 2 billion years ago, bacteria merged: instead of just exchanging genetic material, whole bodies fused together, they penetrated each other and literally started living in each other, as a form of permanent parasitism. These merged beings evolved into protists and multicellular organisms, ending with the evolution of the fungi, plant and animal kingdoms (Figure 2). And, the types of bacteria that fused, still exist today, on their own, thereby excluding any deterministic process: the mergings that occurred, occurred randomly, otherwise we would not see members of these different types alive and on their own today. Bacteria fused literally, by cannibalism or enforced parasitism.

Another interesting aspect of these organelles is that they are passed on from one generation to the next, in a non-Mendelian fashion. Only eggs contain mitochondria or chloroplasts, sperm cells lack these. So every eukaryotic organism, male or female, receives its organelles with their specific genetic

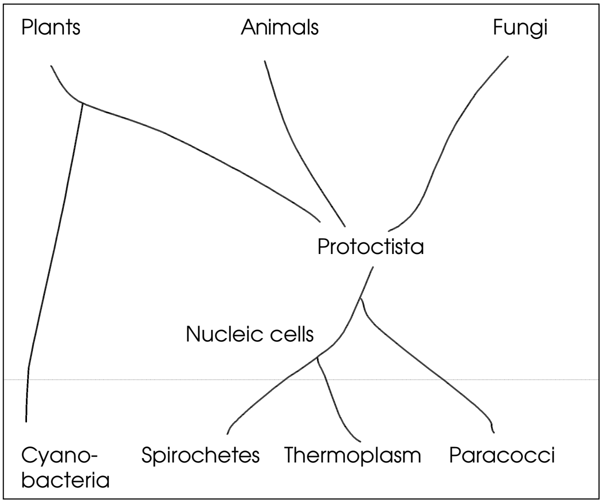

Figure 2. The symbiotic mergers that took place between different prokaryotic organisms (all bacteria beneath the dotted line) that lead to the evolution of eukaryotic organisms (everything above the dotted line). Important are the evolutionary lineages, that instead of forming a splitting pattern, merge (based on Margulis, 1999:41).

material, from the mother. It is hence not true that we receive half of our genetic material from our mother and half of our father.[5]

According to Margulis' theory, we can only talk about 'species' at the level of eukaryotic organisms, where cell fusions are the driving forces of evolution, while bacteria can't be distinguished into species, rather they are classified into different types (that belong to one single species). Mitosis and meiosis always occurs at the level of the cell or between cells. Hence according to Margulis' view, all eukaryotic evolution, even today, during the reproduction of organisms belonging to these four eukaryotic kingdoms, requires a certain form of symbiogenesis. Therefore, this horizontal process needs to be distinguished from a vertical evolution process.

2.2.2. Horizontal evolution by plant hybridization

Plant hybridization is another form of horizontal symbiotic evolution and plants also by far outnumber animals. Plant species that evolved independently from one another can cross-fertilize and produce fertile offspring. This is not a mere vertical process either because what we call incest is a

[5] Exactly because of this can we trace evolutionary lineages by studying Mitochondrial DNA that is only passed on by the mother. The Y-chromosome, on the other hand, is only passed on by the father.

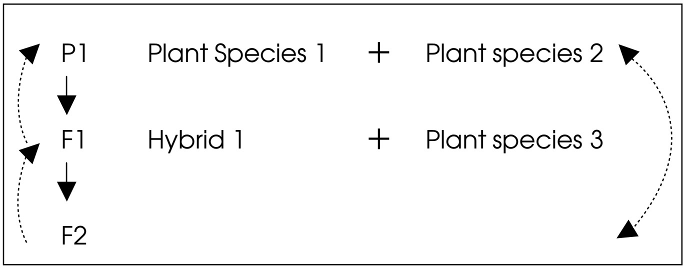

Figure 3. A hypothetical example of how hybridization within plants occurs.

rather common phenomena in hybridizing plants. P1 can be the result of the hybridization of two different plants species, and F1 hybrids can possibly cross-fertilize again with P1. Hybridization can also occur when for instance these F1 hybrids cross-fertilize with yet another plant species and their offspring, for the sake of argument, called F2 hybrids (although they are F1 hybrids of the crossings of F1 with yet another species) and these F2 hybrids can potentially cross-fertilize with P1 or F1 (Figure 3). It is a common thing in plants and indeed these symbiotic mergers are also a form of symbiogenesis, because they always involve the fertilization of whole cells, not merely or solely the passing on of genes.

2.2.3. Inter- and intraspecific horizontal evolution

Bacteria today still donate genes regularly. That is why for instance certain infectious bacteria become immune to antibiotics. Even if bacteria die from a certain antibiotic, suppose that they develop a resistant gene, bacteria that are alive can snap these genes from those dead bacteria.

Horizontal evolution however does not only occur at the prokaryotic level or within the evolution of eukaryotic plants. It can also occur at the intra- and interspecific level within the evolution of eukaryotic life in general, also within the evolution of animals.

SARS (Severe Acute Respiratory Syndrome)-, HIV- and Ebola-viruses for instance (Kahn, 2004) are viruses that are passed on not only between members of the same species (intraspecifically) but also between members of different species (interspecifically).

The recently evolved SARS-virus is a virus that humans caught as a result of eating or being around the masked palm civet, a cat-sized animal. SARS is a variant of a common corona-virus of these masked palm civets. Once one human catches this virus, it can spread very rapidly within the human population at an intra-specific level. It can also be passed on from one generation to the next, not because the virus contaminates the sex cells. Rather this occurs because when there is no external intervention like putting contaminated individuals in quarantine, the population as a whole 'carries' the virus. Newborn babies can catch the disease because their grandparents have it, or grandparents can catch the disease because their grandchildren have it.

The same goes for the HIV-virus which humans caught eating the brains of primates, and primates in turn got the virus eating monkey brains that were infected with the SIV-virus. "*HIV itself has been isolated from common chimpanzees, which are believed to be the original source of the AIDS pandemic after hunters killed and ate them. Ironically, [. . .] chimpanzees acquired their SIV from monkeys they killed and eaten.*" (Kahn, 2004: 58). Once the HIV-virus developed and was passed on interspecifically, it remains in a population, because it is passed on intraspecifically. And Ebola for instance, is now killing great apes, while humans eating these apes, can again infect the human population with Ebola.

Neo-Darwinians do not explain these phenomena as evolution because most viruses do not infect the sex cells and as mentioned above, the researchers only understand two processes to be relevant for the study of evolution: the genes that get passed on sexually, and how these get passed on (mutated or not).

However, ontogenetically, the HIV-virus can get passed on through the blood line (when for instance cutting the navel cord, or drinking the mother's milk). Immunological processes of resistance against certain viruses, for instance, are also passed on through the mother's milk. Infants who are breast-fed are more immune to the development of certain diseases that are caught by viruses or bacteria. This is because through the mother's milk, children receive antibodies (indeed again whole cells) that the mother already made when she, for example, caught this year's flu.

So intraspecifically, there is a lot more going on than the mere transmission of genetic material from one generation to the next because of sexual recombination. Viruses and bacteria which contain their own genetic material can also be passed on in a horizontal ontological fashion. Neo-Darwinian theory is not able to account for, or to formalize these sorts of evolution because of their excessive focus on the sex cells with the subsequent genetic variations and possible mutations.

These forms of contamination as said, can happen at the inter- and intraspecific level, but horizontal evolution, by means of cross-fertilization can also happen at the level of animals.

We of course all know the mule that is the result of cross-breeding with a donkey and a horse. However the mule is infertile and hence Neo-Darwinians define species as those individuals that, when mating with members of the opposite sex, can produce fertile offspring.

However, the Giant Panda (O'Brien and Menotti-Raymond, 1999) is also the result of cross-breeding between the brown bear and other bear species.

Their chromosomes reveal these crossings and most importantly, the Giant Panda is fertile. It is threatened with extinction (because of its vanishing niche but also perhaps because of this genetic load that the animal carries), but the Giant Panda is nevertheless up until this day, fertile.

Neo-Darwinian theory cannot cope with these different, everyday phenomena. Therefore, a horizontal evolutionary concept that can cope is absolutely necessary. That is not to say that Neo-Darwinian theory is wrong, far from it, all that is being said is that there are different phenomena going on within the evolution of life which can very optimistically be explained from within other evolutionary theories.

3. HORIZONTAL VERSUS VERTICAL EVOLUTION IN LANGUAGE RESEARCH

Within the study of language (its origin, evolution and use), both evolutionary concepts are explicitly or implicitly put to use. Most especially a vertical evolution concept is used, explicitly within the study of language, while a horizontal evolution concept is used implicitly.

3.1. Vertical Evolution and Language Research

A vertical evolutionary concept can be distinguished within the disciplines of historical and theoretical linguistics, structuralism and within the Darwinization of language (Croft, 2002) and today takes on the form of the 'language-as-species metaphor' (Mufwene, 2001).

3.1.1. Historical and theoretical linguistics

Although historical and theoretical linguistics are separate disciplines today, both can be understood as part of, and the result of, the sociological systems theory movement described in Gontier (this volume), for they adhere to the view that language needs to be studied synchronically, as a closed, self-explaining and self-encapsulating system.

Language is understood as a static, unevolving entity (Croft, 2002: 75–78) which leads to the entification and reification of language. This essentialism in turn implicitly subscribes to the idea that there is only one (ideal) language or one (grammatical) language structure understood as a Platonic archetype which takes on different manifestations. So the idea arises that there is only one ideal language, that diversifies into different languages. Essentialist thinking is always about distinguishing the accidental from the essential. De Saussure for example developed his three laws. These state that the primary concern of linguistics is about coming to terms with the following three dichotomous relations within language: (a) the relation between lexicon and grammar; (b) the relation between form and meaning and (c) the relation between *langue* and *parole*. These dichotomous relations indeed are instruments to distinguish the accidental from the essential and hence are used to discover the core of 'the' language. This has four major consequences:

(1) Although language can have different manifestations (there are different languages belonging to different language families, there are dialects, and even child language is different from adult language), all these languages belong to the same 'universal' language, because all share the essential properties. The goal of linguistics, according to these theoretical linguists, is hence to distinguish the accidental from the essential and thus to answer the what-is-language question, thereby introducing a functionalistic approach.
(2) Since all languages are different manifestations of one language, all languages are uniform, meaning that there is no directionality to language change (Newmeyer, 2003: 64). If there were directionality, language(s) would evolve and there would be 'lesser' and 'more' languages, but the essential, reified, ideal, universal language is, once evolved, evolutionless.
(3) The principle of uniformity adhered to by theoretical and historical linguists, implicitly implies that, since all languages are essentially the same, but different because of contingent and arbitrary elements such as culture and so on, the essential properties of language transcend everyday language use, and indeed the individual itself, which again leads to an entification and reification of language *outside* an individual organism. This entified structure, which obeys laws of its own, and is not part of the individual members of the species, forms its own structures and behaves on its own.
(4) So when we want to understand language evolution, we need to study this structure on its own, using, for example, the internal reconstruction method and search for the point where this one language started to diversify and have different manifestations, in other words: we need to search for 'the' proto-language, because this will show the essential properties of language.

This by no means implies that today historical linguists adhere to the idea that it is possible to reconstruct 'the' proto-language or that they believe that there was a proto-language from where all languages developed. Newmeyer (2003: 63) gives credible evidence for the fact that we do not know whether there is one language from where all languages developed, but then again we cannot prove that two languages are unrelated either.

And neither does this imply that these historical linguists themselves believe that their internal reconstruction or their use of the comparative method can shed light on the origin of language (Newmeyer, 2003: 71–72). Nevertheless, answering the questions whether all languages share a common descent and whether this gives clues as to how language evolved, used to be one of the goals of historical linguistics, and these goals are the ones under review in this article, for biologists have interpreted them in different ways which has given rise to the general academic climate which will be discussed in the next section of this paper (under Sections 3.1.3 and 3.2).

3.1.2. Chomsky's linguistics

Structuralism evolved out of historical linguistics and here Chomsky (1965) makes his entrée. Chomsky's main goal was to criticize behaviourism which stated that language can be understood without entering the black box that our brain is. Chomsky never denied that we need to understand language from within biology or cognition, on the contrary, this was his main goal. However, he denied that language needs to be studied diachronically, that is, amongst other disciplines making use of evolutionary biology. Because language was uniquely human, the evolution of non-linguistic species in itself could not help the study of human language.

Basically, developing de Saussure's ideas further, Chomsky distinguished between *competence* and *performance*, arguing that only the competence part is relevant for linguistics. This linguistic competence of individuals was believed to be universal: all human beings have access to a universal grammar, a language organ in the brain called the Language Acquisition Device (LAD). Because performance can vary greatly, competence is what needs attention. Therefore, he stated that: "*Linguistic theory is concerned primarily with an ideal speaker-listener, in a completely homogenous speech-community, who knows its language perfectly.*" (Chomsky in Croft, 2002: 76)

And hence here too the primary concern of linguists is to distinguish the accidental from the essential, that is, to search for the proper functions of language and to answer the what-question: "*Hence the logically prior task of elucidating precisely what evolved has taken research priority over elucidating how it evolved.*" (Newmeyer, 2003: 60).

Essentialistic thinking is always associated with asking the 'what-question' (Gontier, 2004). In a very real sense, it was Chomsky who brought the 'what-question' into (biological) linguistics. According to Plato, the archetypes which he talked about, were part of a transcendental reality. One of his students, Aristotle, internalized these archetypes in human and other beings and elements, saying that the 'ideal form' that the Platonic archetype is, is not part of a transcendental reality, but is potentially part of things. This potential needs to be actualized by a process of becoming. In exactly this way, did Chomsky internalize language, saying that the ideal form is part of the brain and that this potential only needs actualization. The point however, is that the actualization process, is not a kind of evolutuion, it needs to be understood as a process of actualizing what was already inherently there (understood as an unfolding).

The result of this thinking is of course that language again gets reified and entified, language in its idealized form (the universal grammar of the LAD)~~on~~ce evolved~~do~~es not evolve anymore and hence is essentially evolution-less. Different from his predecessors, Chomsky states that the ideal entified structure is not somewhere out there, rather it is part of the individual, for it forms an organ in the brain. Universal grammar is supposed to be part of the brain, where presumably a module is formed, where these universal grammatical structures are somehow stored, hot-wired, without these being able to undergo change.

Since natural selection does not work in a manner where something this complex can evolve all at once, without evolutionary intermediates, Chomsky denied any role to natural selection and assumed a qualitative emergent evolutionary step, leading, at one leap, to this language faculty.

It is, however, one thing to assume that we can deduce ideal grammatical structures or rules from a language, and quite another to adhere to the view that these structures actually are somehow part of our brain. We have not yet been able to localize one grammatical rule within that big brain of ours.

3.1.3. Neo-Darwinism

As we have seen, historical and theoretical linguists entified and reified language. Problem then was to locate this reified structure. Contrary to his predecessors, Chomsky localized the entified structure in the human brain, calling it the LAD that took on the form of a module. Basically, Chomsky hence internalized language and combined this view with the principle of uniformity: after all, the Universal Grammar present in all humans which forms the basis for the competence of these humans, is biologically the same. This in turn again implies that all languages share a 'common descent', for all language performances are manifestations of this ideal internal structure.

When battling against behaviourism, the next logical step was to replace instructionist models (that evolved out of behaviourism and stressed the relation between the language structure out there (in a community) and the learning of that structure by individuals) with selectionist models (where natural selection is internalized (Gontier, this volume)).

The first problem to be tackled when interested in a biological, evolutionary study of language is to search for evidence of common descent (in the true sense of the words), that is, to search for commonalities between different languages, and to investigate whether these commonalities are the result of random events, or whether they can be explained in a homologue fashion. "*A biologist interested in exploring the evolution of some structural property of some species will first of all avail himself or herself of the comparative method,* *which involves the identification of homologues to the relevant property in the same species.*" (Newmeyer, 2003: 61).

What is common to all languages was already a problem posed by essentialist theoretical linguists, while what is homologous is a question studied by historical linguists. Although the above mentioned scientists never intended to use these theories when tackling questions about language origins, they nevertheless were interpreted in this way by different biologists.

Pinker and Bloom (1990) developed Chomsky's ideas further, thereby emphasizing the need for diachronic study of language as well. Their main objective is to synthesize Neo-Darwinian theory with modularity theory and the theory of generative grammar. Their idea: "*No single mutation or recombination could have led to an entire universal grammar, but it could have led a parent with an n-rule grammar to have an offspring with an n+1 rule grammar, or a parent with an m-symbol rule to have an offspring with an m+1 symbol rule.*" (Pinker and Bloom, 1990: 753)

This of course is obviously problematic: EE is being applied to fictitious models developed within historical, theoretical and structural linguistics. First of all, there is still no evidence of the existence of a universal grammar that statically is part of our brain. This is still only a hypothesis for we can neither pinpoint a module nor some part or neuron in the brain that contains a grammatical or all universal grammatical rules. It is of course useful to develop this idea further and to look into possible evidence for this theory, but it is another thing altogether to speculate upon a speculation or to assume upon an assumption.

The position taken by Pinker and Bloom is an evolutionary epistemological one: given that organisms evolved by natural selection, and given that certain organisms evolved language which is the result of brain activity and other elements, language itself probably evolved by natural selection and is to be understood as an algorithmic process. No problem up until now, what they take for granted, however, is that natural selection evolved a grammar module, as it evolved other modules (Cosmides and Tooby, 1994; Sperber, 1996) and that these modules are encoded for by genes. This is problematic, for it combines modularity theory, but no module up until this day has been found within the brain; it assumes that there are genes, that encode for such modules, but no gene that encodes for a module has been found; and it takes universal grammar for granted, although we have not been able to locate this either. All these speculations are useful for the development of scientific theories, but speculations alone cannot form the basis of a theory.

3.2. Problems and Shortcomings of a Vertical Evolution Concept in Language

In the analysis above we fully see the merits of EE. EE is not a one-directional discipline that from within biology seeks to develop a normative framework that can be put to use to study other evolutionary phenomena. It is, at a minimum, a two-way process, because difficulties or problems that are obvious in one discipline (for example linguistics), can point to a less obvious but analogical problem within other disciplines where one uses or obtains the general framework from (biology).

That a vertical evolution concept is being used by Pinker and Bloom is obvious, and it will be shown that historical linguists as well make use of such a concept. As Hull (2002: 18) observes: "*In the second half of the 19th century, some exchange took place between historical linguists and evolutionary biologists with respect to the methods that they used [. . .].*" What is crucial is that both linguists and biologists use tree models to classify languages and species, and even more importantly: at the beginning these tree models were not used to portray historical sequences showing common descent, rather they were a-historical sequences of Platonic (and hence essentialist) archetypes. "*The transformation from archetypes to ancestors turned out to be much more complicated than anyone at the time expected. The transition is still far from complete. The Linnaean hierarchy was devised for a-temporal, abstract relations, not historical sequences.*" (Hull, 2002: 24) Theoretical linguistics implicitly took over these observations and methods from historical linguistics, when they implemented sociological, synchronic methods to study language.

The language-as-species metaphor is a direct result of essentialist thinking: languages are entified structures that are either part of the community, or part of the brain. They obey their own laws. Turner (this volume) already showed that the biological species concept is still basically essentialist. Hull (2002: 25) observes that "*[. . .] linguists can be found joining biologists to argue that languages are as much historical entities as are species [. . .]. They come into being, split, merge, go extinct, etc.*"

The definition of language given by Chomsky equals the way biology looks at 'species'. Some members of a species are regarded as ideal representatives of the gene-pool (in technical terms called the 'wild type'), and it is presumed that all organisms share essentially all important genes within a perfectly homogenous population. Hence within biology this is an essentialist view of species (Gontier, 2004; Turner, this volume) and species are still distinguished from one another by dividing accidental from essentialist properties. The wild type is an abstract concept and an objective measure to discover what the essential properties of a species are. All other organisms that are part of that species are regarded as varieties of that wild type.

The language-as-species metaphor (Mufwene, 2001) makes exactly the same mistakes as biologists make: adhering to the view that there is one (abstract) ideal type of language that equals a brain structure that is common to all humans and lies at the basis of the competence, while all acts of performance are regarded as accidental variation, different manifestations from that ideal grammatical structure (the linguistic wild type).[6]

The family tree models used by historical linguists also emphasize speciation. These speciation models imply that at the origin of language, lies one language from wherein all other languages evolved. Just as in biology where it is generally presumed that life arose from one urcell, called the Last Common Ancestor (Gontier, 2004), so it is presumed that language evolved from one proto-language (Bickerton, 2002). Here one can take two directions: (a) One can either, within historical linguistics, try to reconstruct this proto-language, which is regarded as an idealized language, using the comparative and internal reconstruction methods or; (b) one can assume that this proto-language really existed, as biologically inspired scientists like Bickerton (2002) propose.

This idea, again just as in biology, leads to the assumption that older organisms, or older languages, are less complex and hence more primitive than later developed organisms or languages. Hence ideas like the ladder of cone, where organisms are portrayed as evolving towards ever increasing complexity which is obviously false.

This in turn means that if older 'primitive' or 'first' languages are viewed as less evolved, than younger languages are less complex: therefore, Pidgin and Creole languages or child language (Aitchison, 1995) for that matter are explained as a form of proto-language comparable with the first languages ever spoken by human beings.

In other words, these ideas contradict the principle of uniformity which states that all human languages are equally complex. A way out of this is found when one assumes that proto-language differs from human language, because proto-language is not human-bound, rather it is presumed to be a characteristic of the Homo Habilis, Erectus and Neanderthalenis (Mellars, 1998; Bickerton, 2002).

An essentialist view of languages, or species for that matter, implies that one needs to distinguish essential from accidental properties, which in turn leads, for example, to de Saussure who develops three laws to explain what is essential to language.

Languages and (as) species are thus regarded as static entities that cannot mix nor influence each other because they follow rigid evolutionary lines. Language mixing or hybridization cannot be explained using speciation models

[6] The term 'manifestations' here is to be taken literally. Although I cannot go into this argument any further, mutations, 'quasi-species', are always mutations from the wild type: because the wild type~~the~~ dominant genetic sequence in a population, and hence the most reproductive~~ac~~cidentally mutates the most (just the law of great numbers here), mutations always resemble the wild type, and hence are different manifestation of that wild type (Gontier, 2004).

alone, a point also mentioned by Hull (2002: 19): "*The metaphor of a tree of life seems just right for both species and languages, but it can also be misleading. As trees are commonly depicted, they are totally a matter of splitting, splitting and more splitting. Merger never takes place.*"

Hence species or languages ‘die’ when essential characteristics disappear, and are replaced: it is stated that these species or languages go extinct, rather than that they evolved into something new, with different properties. What evolved is regarded to be a totally new language or species.

Turning to the Darwinization of linguistics, again we encounter problems. Today Neo-Darwinian theory tends to reduce the evolutionary process to the process of adaptation. Adaptation strictu sensu means: being able to survive in an environment long enough to reproduce. The emphasis here lies on the survival part. Later on, with the development of the Modern Synthesis, adaptation was defined as being able to reproduce fertile offspring, which in turn was narrowed down to being able to reproduce at maximal speed (fitness). Hence adaptation and fitness today are almost synonymous. More so, the ‘being able to reproduce’ part which still assumes organisms who reproduce today is being replaced with the idea that being adaptive is being able to pass on his/her genes to the next generation, or more abstractly in the gene pool, at a maximum rate (Gontier, 2004).

Popular biological scientists such as Dawkins for instance, also introduce theological elements into evolutionary biology, although they claim to do the contrary. Just as Chomsky introduced functionalistic, Aristotelian methodology into linguistics, Dawkins introduces Aristotelian thinking into biology. Dawkins (2000) defends the idea that it is the task of every biologist to answer the question of why organisms show design. Here it is presumed that there is such thing in nature as design: hands are for grasping, eyes are for seeing, legs are for walking, ... Methodologically, when searching for design features, we need to answer the question of what a certain characteristic is for. The whole point, however, is that in Aristotle’s philosophy, the ‘what’-question and the ‘what for’ question are related (Gontier, 2004). Answering the ‘what’-question is equal to distinguishing between the essential and the accidental and hence equal to defining the proper functions. Since in Aristotle’s philosophy, every final form is potentially present~~it~~ just needs to be actualized by a working agent (related to the how question)~~the~~ ‘what for’-question is related to the ‘what’-question. The ‘essence’ of a thing or organism (what is it, what is the function) is the same as its ‘final goal’ (what is it for).

So when introducing the what-for question, we need an answer to the what question, and when both question are combined, a teleological point of view is taken.

Given this, let us take Dawkins’ argument a bit further: are hands also made for colouring, for typing, are our mouths and vocal cord and tongue made for shouting (anti)-governmental slogans? Obviously a category mistake is being made here.

In evolutionary biology the ‘how’-question is and should also be the most important question raised, instead of trying to give functionalistic accounts based upon concepts like adaptivity with respect to what language evolved for. Needless to say, there are numerous accounts of maladaptive and neutral characteristics of animals (Kimura, 1976; Gould, 1980; Gould and Vrba, 1982). Since we do not know how most things evolved, how can we even begin to answer the question of *why* they evolved, particularly, in a scientific and non-speculative manner? Neo-Darwinians have worked long and hard as well as fruitfully to ban all kinds of theological/teleological thinking within biology. Why on earth should we undo this job?

Pinker and Bloom follow the same road pointed out by Dawkins: language shows design and, therefore, it should have and must have evolved by natural selection, because somehow natural selection gets understood as the designer: the blind watchmaker (Dawkins, 2000). Since natural selection works slowly, grammar (under which form exactly: a module, a gene, an inherited brain structure, is not clear in their work) evolved stepwise as well, leading to a child with an $n + 1$ grammar rule, while his parents got stuck with an n rule grammar. How can this advanced and more complex child make itself comprehensible to his less complex parents?

3.3. Horizontal Evolution and Language Research

As mentioned in Gontier (this volume), EE is about developing a normative framework, based upon evolutionary thinking that can explain all of phylogenetic evolution, but also all of ontogenetic evolution. EE studies the cognitive capacities of organisms from within evolutionary biology (Bradie’s and Harms’ (2001) EEM programme) and it studies how theoretic evolutionary models can be put to use to study the products of these cognitive capacities such as language and culture (Bradie’s and Harms’ (2001) EET programme).

3.3.1. Taking Darwin seriously, EE and universal selection mechanisms

In practice this means that EE gets reduced to finding mechanisms and universal frameworks analogous to Neo-Darwinian thinking. The blind–variation–selective–retention scheme of Campbell (1987), the generate–test–regenerate scheme of Plotkin (1995), the replication–variation–environmental interaction scheme introduced by Hull (see Hull et al., 2001, for the most up to date account), all base their universal schemes upon the evolution of genes by natural selection.

Blind variation refers to the random mutations genes can undergo which leads to variation; the selective retention phase is about the selection of the advantageous random mutations that are heritably retained and spread within the species through time. The same goes for Plotkin's scheme: the genetic material that is generated in the next generation because of sexual reproduction (mutated or not) needs to be tested (by the environment) in order to see whether they are suited for that environment: If the organism carrying these genes is able to survive long enough to reproduce; through reproduction, the genes are regenerated. Hull emphasizes that the level where natural selection acts is the environment which interacts with a phenotype, instead of a replicator (a selfish gene); Plotkin emphasizes the randomness of the testing phase; and Campbell emphasizes the need for retention. However, all these researchers base their models upon the evolution of genetic material by natural selection and extrapolate from hereon to processes like science, culture or language.

So all of them take Darwin seriously, or to be more precise: they take Ruse (1985) seriously, who states that we should take Darwin seriously, although Darwin himself has little to do with Neo-Darwinian theory (Gontier, 2004). Darwin talked about gemulles that can blend, while Neo-Darwinians talk about genes that are impenetrable.

These frameworks surely have their merits, and have helped different disciplines within biology and also throughout the study of complex phenomena within the life sciences; there is no question about that.

Croft (2000), for example, is the first one to actually use one of these normative frameworks introduced by evolutionary epistemologists. He develops a framework of language variation using Hull's replication–variation–environmental interaction scheme. The replicator (the unit of selection) is his view is the *lingueme*: grammatical structures that are replicated in the utterances of people. Variation arises because of phonological and semantic differences that occur in these utterances; and the environmental interaction (the level of selection) refers to the population of utterances (analogous to the gene pool) of people which interact with other such utterances within a language community.

The merit of Croft is that he takes the individual organism as the actor: language is not part of some superorganic structure, it is not out there in the community: language is part of a human being who in his utterances produces grammatical structures.

However, here arise two problems: although Croft is a fearsome critic of Chomskyan linguistics, he does not seem to be able to completely abandon Chomsky's view on language: the universal grammatical rules are unchangeable, perfectly and idealistically part of a brain, and these structures are replicated in an imperfect way within the utterances of individuals. So here he is ambivalent, not using Chomsky while he is using his ideas.

Another problem arises with respect to his idea of a lingueme pool that is analogous to a gene pool, an ambivalence that can also be read in the works of Hull where Croft obtains his evolutionary framework from: although the level of selection is the environment and the unit of selection is the entire organism, that through his genes that make up a phenotype interacts with that environment, ultimately genes or linguemes are all that counts.

Because of these extraordinary developments and the progress made within EE, the time has come to go one step further and to apply evolutionary thinking there where even natural selection, that has been so helpful, fails. Natural selection cannot explain all of life's phenomena (if it were able to do this, then and only then it would be unscientific, for a theory that can explain everything, explains nothing). As said in Gontier (this volume), it is difficult to apply these rigid schemes to language or culture, because it is difficult to pinpoint one unit or level of selection within the evolution of language and culture. Therefore, it is proposed in this article that a symbiogenetic view can complement the study of language from within Neo-Darwinian theory.

3.3.2. Taking symbiogenesis seriously, EE and universal symbiogenesis

Just as the above schemes are generalizations made form evolution by natural selection, so can we develop a general framework using symbiogenesis. Freeman Dyson (1998) was the first to develop a 'universal symbiogenesis theory' that he applied to the evolution of universes and stars, within cosmology. His definition, however, only needs a few adjustments (between brackets), to be useful for the purpose of this article: "*Universal symbiogenesis is the [re]attachment of two [or more] structures, after they have been detached from each other and have evolved along separate paths for a long time, so as to form a combined structure with behaviour not seen in the separate components.*" (Dyson, 1998: 121)

Symbiogenesis thus falls into place as a form of emergent evolution, known by the catchy phrase 'the whole is more than the sum of its parts'. Within universal symbiogenesis, different elements (neither numbered in advance, nor defined in advance, not implying that these elements need to be replicated faithfully, or have longevity or fecundity) that evolved along separate lines (after they got split off from each other or even when they never showed signs of common descent) somehow are combined and this new combination (a structure, element) has new properties, that cannot be reduced to the parts that form the new structure.

This universal symbiogenetic process can be implemented in the study of language evolution in at least three ways: in the study of language variation

(Section 4); language genes (Section 5) and within the study of conceptual blending (Section 6).

4. UNIVERSAL SYMBIOGENESIS AND HORIZONTAL EVOLUTION PROCESSES OF LANGUAGE

Implicitly, sociolinguistics (also called socio-historical linguistics) and anthropological linguistics use a horizontal symbiogenetic concept of language evolution. Sociolinguists and social anthropologists study language variation or language change within a community or a subpopulation of that community and most importantly, they focus on the performance level: they study language as it is actually used by real speakers (Croft, 2002).

They broaden the linguistic synchronic view that states that language can only be understood from within language, and use diachronic studies as well. Hence they contextualize language, using and searching for political, economical, social and cultural factors that influence, effect or even cause certain types of language behaviour.

Typical research topics include language contact, language borrowing, language mixing, language death, bi- and plurilingualism, personal and/or group attitudes towards certain forms of language use (see for instance Crystal, 2002; Nettle and Romaine, 2002; Thomason, 2001) and they find answers as to why these aspects are part of language. Explanations are not reduced to linguistic structures (for example the relations between lexicon and grammar), rather these elements are regarded as being influenced by warfare, trade, colonialism, hegemonic cultural factors, cultural or social markers.

Pidgin and Creole languages, in this view, are not comprehended as static manifestations of a proto-language, but as those languages that give us the best examples of how languages change and vary because of cultural, political, social and economic influences.

These processes are already well and often described by sociolinguists but we should also be able to explain these phenomena in the long run, and form predictions. Therefore, a normative framework is required and symbiogenesis can provide that framework.

First of all, the processes of language variation and language contact resemble the processes involved in contaminations of viruses or bacteria, that are at work at the level of the population. As said: most viruses do not infect the sex cells, but nevertheless stay ‘alive’ within the population from one generation to the next. During colonial times for example thousands of natives were killed because they got the measles from their Western colonizers. Those who survived grew resistant to these infections and now the measles are childhood diseases just as they are in Western countries. These are not the result of genetic adaptations towards the measles. Viruses and bacteria do not form species, but are distinguishable into different types, so within this view there is no need for a language-as-species metaphor. Because when one regards language as a species, one gets into trouble relating this species in itself with the human species.

Secondly, language variation and language mixing also resemble plant hybridization processes. Croft, therefore, introduced the ‘plantish approach’ to language contact and language change: “*The zoöcentric view of phylogeny corresponds to the family tree model of language families in linguistics.*” (Croft, 2000: 196) “*In biology there are very similar phenomena to language contact once one leaves the animal kingdom, moving no further than to the plant kingdom.*” (Croft, 2000: 198)

Thirdly, as symbiogenesis can occur very rapidly (from one generation to the next: bacteria penetrated each other through cannibalism or enforced parasitism leading at once to eukaryotic beings), so language variation and language contact is something that can occur very rapidly within different members of the same population. The Creolization of Pidgin languages mostly happens very quickly, especially when children learn the Pidgin language as their first language (Bickerton, 2002); but when we for instance look at certain dialects or different uses of language as a result of different ages, we too find that they adhere to rapid changes: as a teenager it is popular to use ‘slang’. These teenagers also know how to use their language ‘properly’ and when they work on the weekend or go to school they use this proper form; while going out with their friends they use slang. New words get introduced very rapidly; who used the word computer before 1950 and who did not know this word after 1960?

Fourthly, Neo-Darwinian theory cannot cope with these different aspects of language variation or language change. That for instance [a] gets pronounced as [ae] by one subgroup and as [e] by another, would be comprehended as individual variation (as opposed to mutation that can introduce novelty: what would be translated to linguistics, the introduction of a whole new vowel).

The mechanisms at the base of language variation, however, can get comprehended as a form of horizontal evolution: just as bacteria can exchange genetic material freely within one generation, so languages can exchange grammatical structures, vowels, phonological elements freely. Languages, therefore, show more resemblance to bacterial types than to rigid species. We can leave a coffee shop saying we are going to a [pàrtee] instead of a party.

Freely of course has to be taken with a grain of salt: bacteria, even though they donate and receive genetic bacteria, cannot change from type (spirochetes will never become cyanobacteria). That is why it is important, not so much to study the potential, but the constraints of these organisms. The same goes for language: rather than applying an adaptationist, functionalistic approach to language (the what-for question that automatically and teleologically directs itself to the future), one should study the constraints language has and ask how and when-questions that direct the quest to the past, which is more appropriate when studying origins and evolutions.

5. UNIVERSAL SYMBIOGENESIS AND LANGUAGE GENES

Hurst et al. (1990) was the first to report on the KE-family, a British family where half of the family members suffer from a severe speech disorder (at that time diagnosed as articulatory dyspraxia) that affects their language skills. This pathology was later on diagnosed as Specific Language Impairment (SLI), because besides their overall orofacial an oromotor dyspraxia, the pathology of the affected KE-family members is also noticeable in nonverbal orofacial movements (Vargha-Khadem et al., 1995; Alcock et al., 2000), in their receptive language skills (Vargha-Khadem et al., 1995, 1998; Watkins et al., 2002) and in their brain structures (Vargha-Khadem, 1998; Liégeois, 2003).

In 2000, Lai et al. narrowed the search for the gene responsible down to a specific region on chromosome 7 called the SPCH1 region and finally the gene presumed responsible was identified, called the FOXP2 gene (Forkhead Box, P2). Within the affected family members, this gene has undergone a point mutation (Lai et al., 2000; Lai et al., 2001).

The FOXP2 gene is a regulatory gene that can be divided into two parts: one part contains a large polyglutamine tract; the other part contains a forkhead DNA binding domain, meaning that part of the gene produces helix-turn-helix proteins that are able to (dis)activate other genes, thereby influencing and regulating development.

Enard's team (2002) showed that the human FOXP2 protein has undergone two amino acid sequence substitutes that occurred solely within the human lineage and are fixed within the human population. This fixation converges with the emergence of anatomically modern humans (presumed 200,000 years old) (Enard et al., 2002: 869–870). The FOXP2 gene, however, is an old gene and is very well conserved throughout evolution: since the diversification between the lineages of the mouse and the lineage that would evolve humans, 70 million years ago, there has been only one amino acid substitution, which makes the FOXP2 gene one of the 5% most conserved genes in evolution.

The FOXP2 gene cannot, however, be called a specific language gene, because it is also activated during the development of the heart, the lungs and the gut, nor is it specifically human (given that language is uniquely human, one would assume that language genes would be as well).

This, however, is typical for regulatory genes. Regulatory genes differ from structural genes (genes that encode for proteins that make tissue that eventually leads to the formation of an organism) in that they produce proteins that return to the helix. These have the amazing property of being able to switch other genes on or off, thereby influencing development.

Regulatory genes were first discovered in 1975 by King and Wilson (1975). Ten years ago, a Homeobox of genes was found in our genome (Robertis et al., 1990; Melton, 1991; Wolpert, 1991, 1998; McGinnis and Kuziora, 1994; Gehring, 1998; Davidson, 2001). We share with almost all eukaryotic organisms a Homeobox of genes (called HOX-genes) that regulates the development of our anatomical body plans. Even more interesting is that the same regulatory genes contribute to the development of different species, because of the (dis)activation, elongation of these genes, during different times at different regions during development. The same gene that for instance lies at the basis of the development of a radial symmetrical body plan (such as a sea star), also lies at the basis of bilateral symmetrical animals, such as humans (Schwartz, 1999; Gontier, 2004).

FOX-genes, which the FOXP2 gene is part of, differ from HOX-genes because they are spread throughout the genome, but they share the functional properties of HOX-genes, when it comes to switching other genes on or off.

These ontogenetic processes of gene activation or disactivation need to be comprehended from within a universal symbiotic and hence horizontal point of view, because different genes, after they have evolved in different ways, and were (dis)activated in different regions and periods during ontogeny and phylogeny, can start interacting in new ways, which can lead to the development of new structures and even new species. Hence contextualization and emergentism is what matters (Gontier, 2004), because the newly developed features are not reducible to the mere elements that make them up.[7]

Neo-Darwinian theory, which tries to explain vertical evolution using mathematical algorithms (Dennett, 1995) cannot explain these phenomena using merely these algorithms. An algorithm basically is a linear binary system combined with logic: if gene A is activated (1), then amino acid (a) is formed; if gene A is not activated (0) then amino acid (a) is not formed. Eventually we

[7] An observation also made by Adoutte in a somewhat different context: "The new molecular based phylogeny has several important implications. Foremost among them is the disappearance of "intermediate" taxa [. . .] *We have lost the hope, so common in older evolutionary reasoning, of reconstructing the morphology [. . .] through a scenario involving successive grades of increasing complexity based on the anatomy of extant "primitive" lineages.* [. . .] In this respect, the situation is not unlike the new perspective emerging on the phylogeny of eukaryotes as a whole, in which most of the formerly intermediate taxa have been pulled upwards." (Adoutte et al., 2000: 4455, my emphasis)

get a treelike top–down structure that tries to explain how genes encode for features. However, when we look at the activation or disactivation of different regulatory genes, a network develops, where, if some genes are activated during a certain period at a certain region within the individual, than other genes are switched on or off by proteins that are encoded for by these genes. How many proteins are produced depends upon the activation of certain genes, the locus and the time of development. Regulatory genes are characterized by their pleiotropic effects (Gehring, 1998) and these cannot get formalized using mere algorithms alone. At the very least, non-linear dynamics need to be interwoven with Boolean operators.

And even then it is difficult to formalize how genes encode for characteristics, because mostly a 1–1 correspondence between a gene and a trait is lacking. What we find is that genes act more like risk factors. Schrödinger (2000) already pointed out years ago, that genes do not encode for characteristics or behaviours.

> It seems neither adequate nor possible to dissect into discrete 'properties' the pattern of an organism which is essentially a unity, a 'whole'. [...]*What we locate in the chromosome is the seat of the difference*. (We call it, in technical language, a 'locus', or, if we think of the hypothetical material structure underlying it, a 'gene'.) Difference of property, to my view is really the fundamental concept rather than property itself, notwithstanding the apparent linguistical and logical contradiction of this statement. The differences of properties actually are discrete, [...]. (Schrödinger, 2000: 28–29, my emphasis)

These differences cannot be explained using only Neo-Darwinian theory, a symbiogenetic view, however, can take this emergentism into account.

6. UNIVERSAL SYMBIOGENESIS AND CONCEPTUAL BLENDING

Finally, universal symbiogenesis can incorporate theories such as conceptual blending, developed by Fauconnier and Turner (2002). These scientists understand language as a singularity: there are no gradually evolved grammatical structures and there are no intermediate stages of language, not now, not ever. Language emerged. Emergentism, however, does not imply discontinuity.

They point to two fallacies: the Cause–Effect Isomorphism and the Function-Organ Isomorphism (Fauconnier and Turner, 2002: 175–176). The Cause–Effect Isomorphism is the fallacious idea, widely defended by scholars, that given that the effect is amazing (in this case language), the cause has to be something extraordinary as well.

However, when we look at the development and evolution of regulatory genes, this need not be the case. Far from it: the development of an eye for example is the result of one gene (the PAX6 gene) that switches on 2500 other genes that make an eye. If this gene is not activated, eye development is not triggered (Gehring, 1998). The (dis)activation of this gene, however, is only a tiny step in the process.

The second fallacy put forward by Fauconnier and Turner is the Function-Organ Isomorphism: the idea that with the development of every new function, a new organ is involved. This idea dates back to Aristotle, and is also subscribed to by Chomsky, who presumes the existence of a language organ in the brain. However, nature gives numerous accounts of organs loosing functions or gaining new functions (Gould and Vrba, 1982). Hence Fauconnier and Turner (2002: 177) point out that: "*Language is not an organ. The brain is the organ, and language is just a function subserved by it, with the help of various other organs. Language is the surface manifestation of a capacity.*"

This capacity, according to their view, is conceptual blending (the use of metaphorical or analogical thinking) and language is regarded as just one of the products of this blending capacity.

Here again, we encounter a problem because they adhere to the view that there is a deeper lying, once evolved, unchangeable structure in the brain that has different manifestations, some of these structures emerging through blending. So Fauconnier and Turner too cannot seem to transcend a mere essentialist/potentialist view.

However, conceptual blending can also be understood as a form of symbiogenesis, so therefore, I have redefined conceptual blending just to show how symbiotic this view really is: *Conceptual blending is the combining of two or more conceptual frames that results in a new conceptual frame with meaning not seen in the different components*.

It is important to note that in this definition, the components themselves are not static, unchangeable entities.

7. CONCLUSION

Universal symbiogenesis can be regarded as a complementation of Neo-Darwinian theory, because it can (at the least) integrate the following:

(1) Horizontal evolution, as different from vertical evolution, can be put to use to explain language variation and language change, phenomena already well described by sociolinguistics. However, we also need to be able to explain these phenomena and, therefore, a normative framework is urgently needed.

(2) It can explain ontogenetic and phylogenetic processes concerning regulatory genes such as the FOXP2 gene, by analogy, because the same genes, put in a different context and forming different interactions, lead to new emergent properties.
(3) It can explain cognitive evolutions such as conceptual blending crucial to language, because symbiogenesis can provide a framework to explain these emergent processes that are the result of blending of conceptual frameworks.

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The self-organization of dynamic systems: Modularity under scrutiny

Annemarie Peltzer-Karpf

Language Development and Cognitive Science Unit, English Department, Graz University, Graz, Austria
annemarie.peltzer@uni-graz.at

Abstract

Arguments are running high that modularity pervades all neural organization. As a consequence this hallmark is also to be stipulated for language. This demands the concentration on the overall dynamics of language development and the processes governing the organization of systems. The framework used allows for the spotting of system-specific developmental growth curves each of them depending on the interplay of the given neural infrastructure and the input provided. Of particular importance is the notion that language development does not take a linear path but rather comes in phases of intermittent turbulence, fluctuations and stability apt to swap linguistic borders in mid-stream. The focus is set on bilingual development in immigrant children ($N = 106$; age 6–10) featuring Turkish, Bosnian/Croatian/Serbian and German.

1. INTRODUCTION

In his last book, meandering along 1433 densely set pages, Stephen Jay Gould (2002) proposes a new synthesis of evolutionary theory. Under the heading of '*The synthetic theory of evolution*' Darwin's groundbreaking *'Origin of the species'* of 1859 is given a new appraisal. With regard to neuroscience "*Darwinian evolution has provided organisms with complex, interacting, innate mechanisms; and learning makes the current state of a complex organism (such as a human) an incredibly complex function of its history*." (Sperling, 1997: 257) Viewed from a linguistic perspective "*Darwin took explicit note of a range of possibilities, including non-adaptive modifications and unselected functions determined from structure*." (Chomsky, 2000: 163). The incredibly large number of interdependent interacting mechanisms provides ample research ground for both, the cognitive neurosciences and for evolutionary epistemology (EE). The flaws or pitfalls of Darwin's 19th century reasoning

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can be summarized as follows:

(1) Natural selection does not merely take effect on the organism per se but rather operates its way up from the gene to social groups.
(2) Evolutionary change is not the sole work of adaptation but the result of variegated processes, which go far beyond natural selection.
(3) This change does come in leaps and bounds and is by no means exempted from phase-shifts and catastrophes, so against Darwin's credo 'natura non facit saltum', nature *does* make leaps.

To do him justice it needs to be added that the committed pluralist Darwin himself was convinced that natural selection has been the main but not the exclusive means of modification (Darwin, 1872, ed. by Ekman, 1998). In the given context we shall focus on the distribution of cognitive activity and the emergence of systems.

Following Gould's intricate way of argumentation would go far beyond the scope of this paper. Suffice to say here that Gould tried to combine the classical concepts of Darwin with recent findings of the natural sciences. How non-linearity comes into play will be highlighted in the ensuing discussion of self-organizational processes in various instances of language development.

It is perhaps interesting to note that *The Origin of Species* makes no mention of 'evolution', a word whose sense has gone full circle since its coinage. In its Latin root it referred to the unfolding of a scroll. The word was first used in biology to describe the changes in the shape of an embryo as it developed. Not until much later did 'evolution' begin to suggest the gradual transformation of one pattern into another. Now, its definitions have come together and the study of development is unrolling the scroll of biological history (Jones, 1999: 299). How this scroll unfolds in the emergence of language(s) shall be depicted and discussed in the following paragraphs.

The dynamic approach we take has not only permeated the natural sciences, but the social, behavioural and neurosciences as well. The common link is the idea that seemingly unrelated systems behave in essentially the same way and that the creation and evolution of patterned behaviour at all levels is governed by the processes of self-organization. We start out with a brief of the conceptual foundations of coordination dynamics, synergetic self-organization, shall then turn to the Scylla and Charybdis of cognitive (neuro)science~~mo~~dularity— and finally put our reasoning to test in the arena of developmental linguistics.

To answer to the major claim of EE~~the~~ development of a normative framework, based upon and analogical to biological evolutionary thinking— the developmental paths shall be integrated within the larger framework of embodied cognition (Tschacher and Dauwalder, 2003). This new wave of multifaceted thinking is not merely to be observed in dynamic systems theory but has also found prominent support in the cognitive neurosciences. "*If the* *evolutionary perspective is simply set aside, the data collected by psychologists and neuroscientists alike are likely to be grossly misinterpreted*". (Gazzaniga, 1997: 157). Karl Pribram argues in a similar vein:

> At the very centre of such endeavours is humankind's understanding of its relation to the universe~~and~~ at the centre of this understanding lies the relation between the orders invented or discovered by the operations of this "three-pound universe", the brain, and those in which it is embedded. (Pribram, 1997: 149)

2. THE SELF-ORGANIZATION OF BRAIN AND BEHAVIOUR

Self-organization is a universal principle that nowadays is investigated on any scale of space and time, from the macroscopic to the microscopic. Hence, self-organization applies independently of scale. Our brain, which provides us with the language faculty, is highly self-organized as well. In their neurocognitive interpretation the basic ideas of self-organization can be summarized as follows.

Living systems (defined as open systems since their organization is dependent on the permanent exchange of energy) interact selectively with the environment. The selection of data is carried out on the basis of the presently available criteria; i.e. the respective system determines and enlarges the basis for the further selection and organization of information. Data selection and coincidence detection eventually leads to the organization of non-linear dynamic systems. The processes active in these changes are self-organizing and irreversible. Irreversible processes do not only lead to increasing complexity but also to successive bifurcations or modularity (Haken, 1977, 2003; Prigogine, 1979; Kelso, 1995, 2003).

The organization of non-linear dynamic systems does not merely bring about dissociation once a critical value of complexity has been surpassed but also shows degrees of persistent order. Since the title of this paper makes a feature of modularity the order in which we shall deal with the two phenomena is quite obvious.

3. MODULARITY

The firm conviction that mind and brain were related led phrenologists to map the topography of the scalp and face. Franz Josef Gall and Johann Spurzheim (1808) championed the theory that the mind was made up of a number of separable mental components~~fac~~ulties~~wh~~ich were localized in particular regions of the brain and were associated with particular topographic features of the skull. Faculty psychology has changed the methods (still in use are Brodman's cytoarchitectonic fields of 1909). For modern phrenology the techniques for revealing the macroanatomy (in the range of millimetres to centimetres) of any mental process are clearly available (Uttal, 2001, reports on research techniques).

The bizarre brain charts are a matter of the past; the research question dominating these endeavours is, however, basically the same: Is the brain an equipotential mass or subdivided into components or modules? Greco-Roman thought worked with hydraulic concepts, what we are interested in is a detailed description of the time courses of mental operations in high-level human tasks. The problem is to trace cerebral localization of hypothetical cognitive modules with imaging techniques. In the micron range the cortical column formed by ca. 10,000 neurons is the basic unit. But how to define a cognitive module, if there is such? To speak with Posner and Levitin (1997: 104): "*One theoretical topic that has united philosophy with the sciences is the effort to understand the physical basis of our conscious experience*".

Given the obviously different interests of the parties involved the ensuing discussion will be split up in two parts.

3.1. Neurobiologically Grounded Accounts

In 1949, the Canadian psychologist Donald Hebb formulated his cell-assembly hypothesis, stating that evoking a memory required reconstituting a pattern of activity in a whole group of neurons. The current view of a cell assembly is a spatiotemporal pattern in the brain, which represents an object, an action or an abstraction such as an idea.

Anatomical specialization of function is just one side of the medal; there is also vast evidence for interaction, distributed processing and dense interconnectivity. This neurophysiological enterprise hinges upon the eigenfrequency differences of cell-assemblies in the sense that neighbouring frequency bands within the same neuronal network are typically associated with different brain states and compete with each other. On the other hand, several rhythms can temporally coexist in the same or different structures and interact with each other. These relations between anatomical architecture and oscillatory patterns allow brain operations to be carried out simultaneously at multiple temporal and spatial scales.

We shall explain how this binding of cell assemblies works: A more feasible way to look at cognitive and linguistic processing is to assume local individualized functions which interact to form global context-dependent spatiotemporal patterns of neural activity. This functional coordination among anatomically different parts is ensured by temporal coding, i.e. neurons participating in a particular assembly are distinguished by the synchrony of their responses (60~~80~~ Hz oscillations) (for details see Singer and Gray, 1995; Singer, 1995, 2000). Recent findings indicate that network oscillations bias input selection, temporally link neurons into assemblies, and facilitate synaptic plasticity, mechanisms that cooperatively support temporal representation and long-term consolidation of information (Buzsáki and Draguhn, 2004).

The neurobiologists Edelman and Tononi (2000) strike a similar chord on a somewhat higher level. They propose the rapid reciprocal interaction of functionally segregated brain areas as a solution to binding. These intra-areal connections (or reentry loops) integrate the activity of distributed populations of nerve cells that are strongly interactive among themselves but only weakly interactive with the rest of the system. The basic idea of their approach is the functional clustering of neural activity. A functional cluster is "*characterized by strong mutual interactions among a set of neuronal groups over a period of hundreds of milliseconds*". (Edelman and Tononi, 2000: 139)

Linking up temporal coding with functional clustering shows the following order of mental processes: synchrony first, then clusters and loops. Viewed like that the synchronous activity of particular neural assemblies heralds rapid reciprocal interaction of functionally segregated brain areas. "*Information in the brain has been hypothesized to be processed, transferred, and stored by flexible cell assemblies, defined as distributed networks of neural groups that are transiently synchronized by dynamic connections*". (Buzsáki and Draguhn, 2004: 1928)

Since the search for functional clustering during cognitive activity has just begun and needs to be expanded by imaging methods that offer better spatial and temporal resolutions this (ground-breaking) matter shall be closed here.

3.2. The Modularity of Mind

The title of Fodor's benchmarking essay of 1983 poses as the heading of this section. Fodor not merely brought Franz Gall's early 19th century phrenology back to memory but he also enticed a series of new theoretical and practical research on modularity. The hunt for modules can be traced in generativist and connectionist research camps. In developmental linguistics most of it is linked up with the nurture-debate and, under the heading of *building block models*, the temporal asynchrony of system development (see Hohenberger, 2002: 27–31; Tracy, 2001). Since the issue at stake in this paper is the functional dissociation in the development of linguistic systems we shall postpone the discussion to Sections 5 and 6.

The previous section has shown that leading neurologists consider the intrinsic differences between the individual components as sufficiently large that they do their own work, while still retaining a tendency to cooperate. So how are patterns of phase and frequency synchronization between neural regions of the brain accounted for in the cognitive sciences? What me may well assume as a common denominator is the idea that "*Consciousness must be the result of activity distributed throughout the whole brain*".(Tononi and Edelman, 1998: 1847) Whether brains accrue specialized systems through the process of natural selection had better be answered by EE.

Fodor (1983) rather refutes any tendency for the simultaneous coexistence of integration and segregation and, above all, he favours innate knowledge modules. In his essay on the modularity of mind he argues for input and output systems: In the wording of his former teacher: "*The cognitive system of the language faculty is accessed by such systems, but is distinct from them*" (Chomsky, 2000: 117). Fodor stands for modularity in all sensory systems (input and output), but isotropy in the cognitive domain (central systems). We list the famous and hotly debated hallmarks of modular systems:

(1) domain specificity
(2) mandatoriness
(3) informational encapsulation
(4) speed
(5) lack of access by other systems
(6) shallow output (= semantic poverty)
(7) neuronal localization
(8) susceptibility to characteristic breakdowns.

Fodor limits modularity to a narrow part of the mental domain~~se~~nsory and perceptual processes defined by the differential sensitivity of the various receptor organs. "*There is practically no direct evidence, pro or con, on the question whether central systems are modular*". (Fodor, 1983: 104). Although Fodor's concept has been very influential, evidence has been building up in support of the view that many central systems too are broadly modular in structure. As discussed in the previous section neurocognitive research over the past 20 years is rather assertive there: "*Often the future is a return to views expressed in the past but with new insights based on technical innovation and experimental results*". (Pribram, 1997: 142).

Noam Chomsky is more holistic in his approach, he too adheres to modularity on a more global level and starts with internal splitting once the autonomous status of language in the human brain is asserted: "*The brain has a component—call it 'the language faculty'—that is dedicated to language and its use*".(Chomsky, 2000: 77) So what we get from this angle is the information that (1) abstract thought and language are embedded in the brain by evolution as specially dedicated modules and (2) that they are innate, or in the wording of Steven Pinker: "*The mind is organized into modules or mental organs, each with a specialized design that makes it an expert in one arena of interaction with the world. The modules' basic logic is specified by our genetic program*". (Pinker, 1997: 21)

The following sections will bring about a shift in the research paradigm: modularity goes dynamic. What we fully approve of is Chomsky's idea that "*The full range of properties of some construction may often result from interaction of several components, its apparent complexity reducible to simple principles of separate subsystems*" (Chomsky, 1981: 7). But there is absolutely no consensus with the innate specification.

Transporting the modularity debate back to the dynamic level brings about a discussion of instabilities and stages of persistent order. Taking a far-sighted perspective Thelen (2003: 18) argues for the grounding of mental activity "*in the continual perceiving the world and acting in it, not just as the initial state, but throughout life*". Holding it up with the late Ilya Prigogine (1979) we are to expect successive bifurcations which bring about a more coherent state, relating life to a cascade of instabilities. To reduce chaos we shall contend ourselves with a shorter and yet exciting time-span in our lives, i.e. early childhood and adolescence, and delegate the discussion of Poincaré's iterative cycles between chaos and order to a macroscopic forum.

3.3. Modularity and the Nature–Nurture Debate

To cut a long story short there are two positions concerning our natural endowment (most ardently debated by the late Jean Piaget contra Noam Chomsky amidst a vividly participating audience; for a detailed account of this legendary encounter see Piattelli-Palmarini, 1980).

Position A starts from the assumption that the infant is born with innate modules and core knowledge relevant to the physical and social world. The functional specialization of regions of the cerebral cortex arises through intrinsic genetic and molecular mechanisms and experience merely has a role in the final fine-tuning.

Position B holds that many of the changes of behaviour observed during infancy are the result of general mechanisms of learning and plasticity. According to this view there is a continuous interplay of intrinsic genetically determined and extrinsic environmental factors at all stages of development: at the ventricular zone during neurogenesis, in the cortical plate during parcellation of cortical areas and within the cortex during formation and maintenance of cortical networks (for details see Rakic, 2000; Sur and Leamey, 2001).

Some aspects of functional brain development involve a prolonged process of specialization that is shaped by postnatal experience. The development of cognition thus depends on the functional capacity of the underlying neural circuitry, or more precisely: the complexity of patterns processed at a given age is determined by species-specific brain growth spurts and the input provided by the environment. Furthermore when talking about plasticity we should consider that learning involves the development of entirely new circuits with new and previously unused elements as well as the modulation of older circuits and connections. Viewed in this context neuronal plasticity can be defined as the brain's capacity to get organized and to reorganize itself as a reaction to internal or external changes. These conditions hold for all instances of our neural repertoire beginning with the most elementary functional unit, the neuron, on to the long and short distance links which connect the various parts of the brain, up to the cortical centres on top of the hierarchy.

Given intensive research on brain development there are substantial data speaking against intensive pre-wiring (see Gazzaniga, 1995; Rakic, 2000; Nelson and Luciana, 2002). The party line of the cognitive neurosciences holds that the many layered activities required in language processing can be solved by the synchronization (and clustering) of the respective neural aggregates and that Universal Grammar needs organization, meaning that language data do not come packaged with instructions for their own analysis (more along these lines in Elman et al., 1996).

In recent years the modularity debate has been fuelled by data pouring in from various developmental studies. Of particular interest is the genetic foundation of specialized systems; i.e. the extent of their innateness. Due to major advances in neuroimaging and genetic research some of the hitherto acknowledged modules had to be redefined (Uttal, 2001). This holds especially true for the innate fixation as envisaged by Chomsky, Fodor and Pinker. In contrast to the generativist idea of pre-specified modules, the (neuro-)constructivist partyline holds that the extent of innate specification of modules may be fairly minimal at birth.

To do justice to Chomsky's modularity concept it needs to be said that the subsystems he envisages in his 1981 Government-&Binding Model meet their counterparts in studies on language development in ordinary and exceptional circumstances (Bellugi and St. George, 2001; Hohenberger, 2002; Tomasello, 2003). Modules in the initial state of the language faculty, however, will be difficult to trace. The same holds true for the innate repertoire of unmarked grammatical phenomena (Universal Grammar) which are to be adjusted to the exigencies of a given language (parameter setting).

Rather unspoilt territory for the tracing of modularity has been sighted quite recently. In a joint behavioural study (Nathalie Gontier, this volume) with Marc Hauser and Tecumseh Fitch, Chomsky expands the scope of language study to the investigation of complex behaviours in animals (Hauser et al., 2002). It does not come as a surprise that the activities in Noam's ark (Bever and Montalbetti, 2002) focus on syntax. Chomsky's redefined cognitive computational faculty comes in two forms: FLB (Faculty of Language in a Broad sense) and FLN (Faculty of Language in a Narrow sense):

(1) FLN only includes recursion (the engine driving syntactic computations) and is the only uniquely human component of the faculty of language.

(2) FLB contains the rest, i.e. other contributing biological features: a sensory-motor system, a conceptual-intentional system, and the computational mechanisms for recursion, providing the capacity to generate an infinite range of expressions from a finite set of elements.

So what makes us so unique is our capacity to combine and to do that again and again. Or in a more technical parlance: The essential feature of syntax is recursion, the ability to generate an infinite array of expressions from a limited set of elements, which are merged and displaced (merging relates to the combination of (lexical) units in a hierarchical structure; displacement works on a unit previously merged by merging it again at a different location in the structure and leaving a copy of it behind). In the conclusion to their richly illustrated paper the authors hypothesize that FLB probably emerges in a modular and highly domain-specific fashion:

> [R]ecursion in animals represents a modular system designed for a particular function and impenetrable with respect to other systems. During evolution, the modular and highly domain-specific system of recursion may have become penetrable and domain-general (Hauser et al., 2002: 1578).

The framework we use now falls under the heading of self-organization. We start with a brief definition, followed by a dynamic systems account of language development in a bilingual context.

4. EMERGENT STATES: A CASCADE OF INSTABILITIES

"*Self-organizing systems are creative at various levels, for instance, a newly evolving pattern is surely quite different compared to a homogeneous state. Thus following up a hierarchy of newly emergent states, we may surely state that such a system is creative*". (Haken, 2003: 16). The source of this creativity and hierarchical complexity in living systems is chaos, defined as temporally irregular structure. Chaos leads infinitely to many possible states and splitting of clusters, that is changes at local level can trigger off global reorganization processes. Roughly speaking there are two phenomena to be observed in the evolution of systems, i.e. the turbulent state following the onset of chaos and the switching among coexisting attractors.

4.1. The Chaotic Itinerary

That chaotic behaviour does not necessarily imply that everything is random, is borne out by the well-known regularities in the way in which chaos develops, for example by bifurcations or period-doubling. The problems of a sufficient empirical foundation are discussed by Lightfoot (1991: 165): "*Techniques for analysing chaos are 'data-hungry', and it is hard to determine whether fractal attractors exist for some body and data unless there are enormous quantities of data*".

In a large-scale study on processes of self-organization in linguistic ontogeny: first and second language(s) we were able to show that the assumed linguistic modules, i.e. the lexicon, morphology and syntax are initially undifferentiated, but become modularized and lose their coupling in the course of development (Karpf, 1990). So modules are not part of our natural endowment but rather develop over time.

The empirical evidence is drawn from 500 subjects (age groups 6–46 years). The study belongs to the very paradigm of physiological self-organization which Singer (1987) had developed before. The results are mostly compatible with the selectional approach of Chomsky (1981, 1988, among others; see Sections 3.1 and 3.2). Karmiloff-Smith (1992: 4) reaches similar results: "*I hypothesize that if the human mind ends up with any modular structure, then, even in the case of language, the mind becomes modularised as development proceeds.*" How cognitive dissociation and innate modularity go together is topic of a further study on Williams Syndrome known for the dissociation between visuospatial and language abilities (Karmiloff-Smith et al., 2003).

The transition from a non-chaotic selective framework to a full-blown chaotic selective framework (Karpf, 1990, 1993) yielded at chaotic itinerary to language which has proved quite helpful with the description and explanation of non-linear phenomena in various instances of language development (Peltzer-Karpf, 2003).

Ferreting out bifurcations in cognitive systems implied the use of cross-correlation as a statistical tool. In our study we applied correlation tests (t-test and Pearson correlation coefficient) to large quantities of data. Initially, a strong coupling between subsystems, or modules, is observed (evidenced by high t-values). At the same time there is a high fluctuation in the use of forms and rules. Later we were able to observe decreasing coupling (evidence in falling t-values). In the first place the t/t data in the inflection/lexicon, inflection/syntax and word formation/syntax correlation pairs took a rapid decline between 6 and 8 years. A parallel system-internal dissociation could be observed within the individual word formation processes of English and German, respectively, in particular between compounding and derivation. Thus, phase transitions take place by which the global and undifferentiated system is irreversibly modularized. The picture of an energy-consuming, branching structure emerges, due to the search for coherence and balancing processes leading to clusters and bifurcations (Karpf, 1993: 7).

What we should like to propose here is a kind of phase diagram outlining the relationship between chaotic states of a complex system with global

initial state (inhomogeneous clustering)
quasi stable state
turbulent state (desynchronized part) ← Onset of chaos, turbulences & fluctuations
intermittent state (clustering)
partially ordered state
ordered state
coherent state (large coupling strength)

self-organizing processes shaping an inhomogeneous basis into a highly-specialized system of interacting modules

Figure 1. The chaotic itinerary and self-organization: nonlinear processes lead to synchronized patterns of activity.

coupling in which the phases are characterized by differing degrees of persistent order. The model (owing to Kaneko, 1990) hinges upon a chaotic itinerary between complete randomness in the initial state and synchronous behaviour by coupling in the final state.

The abridged spelt-out version of Figure 1 reads as follows: The *initial pseudo-stable state* (comprising pre-speech behaviour) exhibits a transition from holistic to gradual analytic decoding; linguistic behaviour is dominated by the search for coherence expressed in memorized (non-analyzed) chunks and restricted variation. The *intermediate stages* are characterized by the extraction of rules alongside with the (re-)modelling of neural connections, the reorganization into different clusters and the onset of system-specific phase-shifts (heralded by over-productivity and fluctuations). The *final steady state* shows coherent clusters and uniform patterns with large internal coupling strength and stability towards unordered input.

In brief the dynamics of language development sets out with a holistic phase dominated by memorized chunks which are then submitted to system-specific fine-grained analyses once development allows for higher order processing. Internal system-wide changes are dependent on a continuous interaction with the environment and only occur after a critical mass of lexical data has been accumulated (for details see Hohenberger, 2002).

The switch among attractors (roughly speaking anything towards which a system is moving or can be drawn) appears in the transition between two sets of clusters (a system may have several attractors, in our case paradigms or rules). This switch changes the distribution of clustering, accompanied by a bifurcation-like phenomenon. The initial state shows subtle correlations between clusters at best. From a dynamic point of view over-productivity and fluctuations herald modularization, i.e. the functional specialization and autonomy of systems, and system-specific phase-shifts. What bilingual language development can do to an incipient system is shown in Section 6. Of

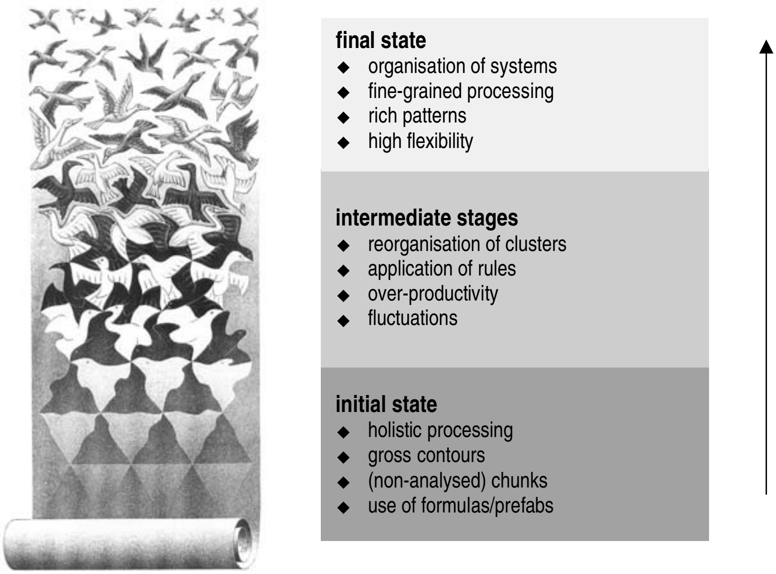

Figure 2. Changing patterns: M. C. Escher (1955), *Bevrijding/Liberation* and the chaotic itinerary of language development.

particular interest is the considerable amount of time it takes to balance syntactic positioning and morphological agreement.

Figure 2 depicts the transition from holistic to gradual analytic decoding described above. In addition it meets the original sense of the word *evolution,* the unrolling of a scroll.

For Chomsky drifting towards new horizons in the study of language opens up the following research questions: How do the genes determine the initial state, and what are the brain mechanisms involved in the initial state and the *later states it assumes*? (Chomsky, 2000: 5). The answers will most probably be delegated to cognitive neuroscientists, but Chomsky definitely scores a (dynamic) point with the italicized final part.

To pave the way for the discussion of bilingual development in immigrant children we now highlight the first years of language development which set the scene for the organization of additional languages.

5. A BRIEF ON FIRST LANGUAGE DEVELOPMENT

Language development is a multisensory activity relying on the dynamic interplay of the child's brain and the environment. Dynamic in this context means that the given state of neural development sets the pace for the intake and further processing of information. Neurophysiological research has shown that neurons do pick their favourites in the input. This becomes evident in the relatively high discharge rates to optimal stimuli and in the synchronized responses of nerve cells, which are tuned to the same type of stimuli (see Section 3.1 for assembly coding and clustering). One of the first feature qualities to be attended to is saliency. Further candidates are frequent and transparent stimuli, which together with salient *pop-outs* play a prominent role in early language development. As life goes on, the dynamic interplay of the neural repertoire and the input brings along a shift in the nature of salient features. It might be opportune to mention a major brain-spurt (1 out of 12 between birth and 21 years) around 24 months, when synaptic density and metabolism have their heyday (details in Gazzaniga, 1995, 2000; Nelson and Luciana, 2002). Alongside with the growth of long-range nerve fibres and the on-going myelination of nerve sheaths this opulent basis offers ample opportunity for the mapping of external situations onto inner states.

Infants show different developmental courses for different segmentation tasks. The activities involved there are (1) the recognition and extraction of single units from a stream of speech sounds, (2) the segmentation into smaller units and storage of chunks, (3) the (re)analysis of stored units and the extraction of morphosyntactic frames and (4) the discovery and application of rules. Given the non-linearity of these processes development does not come gradually but in bursts and leaps. The major phase shifts up to the age of three can be summarized as follows (Zangl, 1998; Hohenberger, 2002):

(1) between 1.5 and 1.8 years: a rapid lexical increase
(2) around age 2: first evidence of morphological and syntactic variants
(3) between 2.4 and 2.6/2.7 years: stabilization of S-V-congruency followed by higher syntactic mobility and productive use of morphological markers (increase of overgeneralizations).

Interdisciplinary research has shown that scene-segmentation runs from holistic to fine-grained in all domains, i.e. the specification of neural processing correlates with the eventual fine-graining of gross contours favoured in early childhood (see Neville and Bavelier, 2000; Peltzer-Karpf and Zangl, 2001). In vision this implies a developmental order starting off with the appreciation of arrangements of discrete elements that constitute a global form (3–4 months), leading to the discrimination of subject contours (4–5 months) and the segmentation of textures defined by an orientation contrast (5–6 months). Segmentation and binding mechanisms are immature in the youngest infants (i.e. they are not functional before 1 year of age), still developing throughout school age and achieve their optimum in late adolescence. This protracted developmental course of segmentation might reflect the overall maturational sequence of processes in the juvenile brain. All things considered the perceptual system must develop the ability to define object boundaries, fill in missing information and bind together different features to compose whole unitary objects.

In a second sidestep to developmental neurobiology we should like to point to a growth factor which is highly influential in scene-segmentation, i.e. neural plasticity, which in this context is interpreted as the brain's capacity to respond to ever changing input constellations. The early years are ruled by a transient exuberant connectivity which provides an initial diffuse array of connections out of which the mature patterns can be sculpted. Later on the availability of large pools of functionally unspecified nerve contacts (synapses) closes down displaying a scale of plasticity. This system-specific loss is preceded by *critical phases* in which a system is most susceptible to changes. The individual critical periods probably correspond to the time when excess connections are present and modifiable by experience-related neural activity (Peltzer-Karpf, 2003).

We now cede the floor to the discussion of dynamic systems theory linked up with the acquisition of language.

5.1. The Dynamics of Early Language Development

This new way of data analysis is clearly process-based and gives insights into the inter- and intra-related development of (sub)systems along the evolutionary path. What matters are the internally and externally driven *motors* of change becoming apparent on the micro- and macro-level. In order to follow the developmental trajectory along the arrow of time moving from a previously global and relatively undifferentiated state to an increasingly fine-grained and functionally complex mosaic the following phenomena are of particular importance: the selection of input data, the emergence of varying degrees of order (= system dynamics) and the dissociation of (sub)systems as a result of increasing system complexity, i.e. the rise of modular organization within the developmental course (for details see Karpf, 1990; Kelso, 1995, 2003; Hohenberger, 2002). What we definitely find ourselves with is an intricate web of additive (linear) and non-additive (non-linear processes) which take their irreversible path to the final state and require for longterm studies to understand the way a system has gone through. As Jay Gould so aptly stated in a book he did not live to see published:

> [J]ust knowing the properties of each part as separate entity [. . .] won't give you a full explanation of the higher level in terms of these lower-level parts because, in constructing the higher-level item, these parts combine and interact. Thus one must also include these interactions as essential aspects of an adequate higher-level explanation. (2003: 221). Or in the wording of Ilya Prigogine: "*understanding stage C requires the study of stages A and B*". (1979: 120)

Generally speaking the speed and intensity of pattern organization is dependent on (1) the respective biological and linguistic a priori, (2) the amount and quality of the input and (3) system-internal reorganizational processes. In first language development several major phase transitions have been traced up to the age of three. They occur at more or less regular intervals and bring about waves between silent and explosive periods (cf. Zangl, 1998). The age of two seems to be a particularly blooming period when significant changes in all systems take place both within mono- and bilingual development (cf. the brain spurt cited above).

Summing up this developmental part it can be said that maturational factors and experience play complementary roles in forming specialized systems, which display different degrees of experience-dependent modification and operate at different time scales. The child's task can be specified as organizing an array of overlapping signals, contrasts and contours, which in language learning translates to discovering phonetic features, word boundaries and grammatical regularities. As time goes by syntax shows a clearer surface marking with regard to prosodic padding, the positioning of elements and case-marking (if required by the system); morphology scales up from compounding to derivation giving priority to affixation over internal changes (here again respecting language specific priorities). Lexical organization starts out with a linear growth followed by the non-linear reorganization of the data-pool.

The search for coherence and the strife for rule-governed behaviour (with intermediate turbulences) will now be illustrated by samples taken from a longterm study on bilingual language development in immigrant children.

6. THE BILINGUAL CHAOTIC ITINERARY

This chapter places dynamic systems theory into a multicultural setting. The developmental stages ascertained for monolingual preschool and primary school children are put to test in an asynchronous situation of bilingual language development. The data are drawn from a research project on bilingual development in immigrant children[1] ($N = 106$) featuring the combinations of Turkish and German or Bosnian, Croatian, Serbian and German. In both situations the lopsided developmental enterprise was challenged with a sprinkling of primary school English. The focus is set on the interplay of systems along a 4-year trajectory with the control parameters set by monolingual children in Austria, Bosnia and Turkey. Each of the children was followed up from age 6 to 10 in his/her own linguistic career. The individual languages were given a regular psycho- and pragmalinguistic scrutiny (including the frog story), transcribed in CHILDES and then submitted to a dynamic cross-linguistic

[1] Funded by the Austrian Ministry of Education, Research and Culture (in the years 1999–2003).

analysis. The outcome is a vast data-pool which allows for the tracing of fluctuations and turbulences along increasingly intertwined chaotic itineraries with different onsets and developmental conditions (details in Peltzer-Karpf et al., 2003).

Of particular interest is the question how a lopsided start into a new language influences the ongoing development of the first language. In linguistic terms the prospective temporal asynchrony takes the following stepping stones in the intake and further processing of information: while starting with the search for coherence in the new language immigrant children keep sorting out the more sophisticated morphological and syntactic patterns of their first language, enrich and reorganize their lexical repertoire and work out explicit rules for the management of discourse and textual structures. A more intensified scene-segmentation in the minor language soon creates a state which shows all the signs of cross-linguistic chaos, i.e. turbulences and fluctuations expressed in the over-generalization of rules, excessive morphological marking and free-floating syntax. The investigations carried out so far provide evidence for a changing sensitivity to language cues at different times and structure-specific time scales for system development. Of particular importance is the notion that successive bilingual language development does not take a linear path but rather comes in phases of intermittent turbulence, fluctuations and stability apt to swap linguistic borders in mid-stream.

Under these auspices the chaotic itinerary introduced in Section 4.1 will be given a more specified and age-related interpretation:

(1) *The pseudo-stable stage: copying of unanalyzed chunks:* Linguistic behaviour shows (non-analyzed) chunks and restricted variation. Morphological markers are generally limited to frequent chunks and imitations. Apart from pre-fabricated, memorized (all-purpose) formulas or routinized patterns the initial state is dominated by ill-defined cuts in word-segmentation, simple hybrid sentences and foreignizing, defined as selling L1 material under cover of L2-phonology to fill lexical gaps in the new language.

(2) *The turbulent/chaotic stage: extraction of rules:* The intermediate stages bring about an array of activities which are enumerated in the following list: the reduction in the number of prefabs, a marked increase of MLU (mean length of utterance), the fluctuating application and over-generalization of rules, a clear preference of salient and frequent patterns and the movement of elements and morphological marking. The hallmark of this state is the dissociation of a hitherto undifferentiated system into specialized sub-systems (modules) with their own developmental speed and vulnerability.

(3) *The final state: coherent patterns and great stability:* Most important to note is that the final state shows coherent clusters and patterns with large

internal coupling strength and great stability towards unordered input. Internal system-wide changes are dependent on a continuous interaction with the environment and only occur after a critical mass of lexical data has been accumulated, i.e. increasing lexical storage leads to the onset of rudimentary sentence and word internal analysis and can thus be seen as an essential precondition for increasing word and sentence internal depth of analysis.

Apart from these system internal processes, which can also be observed in monolinguals, bilingual development is marked with two phenomena: (1) cross-linguistic processes and (2) temporal asynchrony of system development within and across languages. Temporal asynchrony can also be ascertained in a monolingual situation meaning that the individual systems develop at a different speed. Asynchrony of system development shows quite early in bilingual children. Growing partner orientation and the accumulation of linguistic data lead to increased code-mixing and code-switching in the chaotic phase (Döpke, 2001).

What we get here is a situation which responds to the perspective of self-organizing coordination dynamics, namely its focus on qualitative change in places where behaviour bifurcates or a phase transition occurs. Many variables may be changing, some smoothly and linearly. Undoubtedly such competitive interaction between behavioural task demands and individual coordination tendencies leads to observed biases and increase in variability of the performed pattern (see Kelso, 2003).

6.1. Instabilities

Theoretically speaking, dynamic instability is the generic mechanism underlying spontaneous self-organized pattern formation and change in all systems, coupled to their internal and external environment. How the two interact can well be seen in the exceptional situation of bilingual development where control parameters and attractors create havoc with linguistic systems in the turbulent phase.

The matter at issue is changes in the stability of systems, which affect above all the scope of control parameters. Technically speaking a parameter is a control parameter which, when it changes smoothly and continuously, causes a qualitative and abrupt change in the coordinative behaviour of the system. Thus, when a control parameter crosses a critical value, instability occurs, leading to the formation of new (or different) patterns. And given the non-linearity of rules small changes sometimes produce large effects and large changes no effect at all. All things considered the global linguistic systems may be seen emerging from the non-linear interactions among subsystems (Haken, 2003; Kelso, 2003; Thelen, 2003).

Looking at the following data (assessed individually from age 6 to 10) we might come to the conclusion that information is capable of stabilizing the coordination dynamics even under conditions in which patterns of coordinated activity typically become unstable and switch. The following examples illustrate language internal and cross-linguistic processes.

6.1.1. Language internal processes

(1) Double marking in genitive-possessive constructions (L1 Turkish,[2] age 6)

bu-n-un dolab- ı
REF-CONS.INSERT-GEN-chest-POSS.3SG
'of his chest'
bu-n-un dolab- ı-s-ı
REF-CONS.INSERT-GEN-chest-POSS.3SG-CONS:INSERT-POSS

(2) Simplification of gerund forms (L1 Turkish, age 8)

Erdal hasta ol-du, ne yap-ıyor?
Erdal-ill-be.2SG.PAST-what-do.3SG.PRES
'Erdal got ill, what will he do?'
Erdal hasta o-lunca ne yap-ıyor?
Erdal-ill-be.ADV-what-do.3SG.PRES.
'What will Erdal do when he gets ill?'

At veritable hotbed for the observation of changing pattern preferences and system activities are the subsystems of morphology. Technical details can be spared here but it is a good moment to refer to a highly workable model which was launched by the late Willi Mayerthaler in 1981. His internationally acclaimed natural morphology is based on the interaction of various principles such as markedness, ease of processing, transparency and frequency. Natural forms show a constant form in that they are not or only slightly affected by morphonemic alternations in derivational processes (like fusions, truncations, palatalizaton or velar softening) and they are winners and survivors in language change, come to the fore in Pidgins and Creoles, are the first to be learned in first and second language development, keep longest in aphasia, and are turned to when it comes to creating new forms.

Given our dynamic view of system development in a bilingual context we now cite examples of the interim stages of the morphological trajectory in which naturalness is challenged by the onslaught of data and rules. Suffice to say here that the dissociation of morphological systems

[2] Thanks go to Reva Akkus for her help with the analysis of the Turkish data.

is accompanied by a phase of over-productivity (Karpf, 1993). Changes in the distribution of clustering are caused by the omission of grammatical morphemes, double marking, over-generalization and the alternating use of forms.

A hurdle in the acquisition of German is vowel replacement (*umlaut*) which works as an autonomous rule in inflection and word-formation. We brief the rules for German plural: 15 unstable classes; the unmarked forms are masculine: *umlaut* + *{-er};* feminine:*{-(e)n};* neuter: *{-er}* coming up with zero marking, suffixation and umlaut (plus suffix). Despite these intricacies, after 4 years of training the immigrant groups ranked as high as 83% (Turkish) and 92% (BKS) in psycholinguistic tests.

(3) German plural (L1 Turkish, age 8)
Buch → Bücher
'book → books'
Büch—Büche—Buchen—Büchern

Verb inflection poses similar problems with the umlaut and the use of affixes. The irregular verbs in (4) follow the regular pattern (with double marking in one case):

(4) German verb inflection (Turkish & Bosnian/Croatian/Serbian, age 8–10)
Und die Fische verschwindeten.
verschwinden—*verschwand(en)*~~ve~~rschwunden
'And the fish disappeared.'
Die großen Fische nehmten den kleinen Fisch.
nehmen—*nahm(en)*~~ge~~nommen
'The big fish taked the small fish'.
Der Mann ging-te traurig nach Hause.
go.PAST.PAST
gehen—*ging*~~ge~~gangen
'The man wented sadly home.'

The dissociation of morphological systems is accompanied by a phase of over-productivity which is characterized by an excessive activity in word-formation and by the violation of morpheme-structure conditions. The examples (5–7) show language internal chaos within the first and the second language expressed in morphonological processes applied to extended or truncated lexical roots. Compared to compounds, which scored high in all groups, derivation showed a considerable time-lag in all the languages involved:

(5) adjective formation (L1 Bosnian/Croatian/Serbian, age 9)
Wolke → bewölkt/ wolkig
'cloud → cloudy'
wolknisch—wölklich—wolkerisch—wolkelig—bewolkt

(6) agentive derivation (L1 Bosnian, age 9)
zidati → zidar
to lay bricks → brick-layer
zidač—zidarč—zidac—zazidavač

(7) agentive derivation (L1 Croatian, age 10)
prodavati → prodavačica
FEM
'to sell → seller'
prodavanica—prodačica—prodavica—prodajka—prodajnica—predačica
prodavčica—prodajica—prodivnica—prodejica—prodakinja

With bilingual children the race for the final state can be observed within the two languages they are about to acquire and in between the two languages involved in their developmental enterprise.

6.1.2. Cross-linguistic transfer

(8) hybrid word formation (L 1 Turkish, age 7)
dört eck-leri var
four-corner.PLURAL-have.3SG.PRES
'It has four corners'.
dört-eck
four-corner.SG
'square'

(9) structural change in word formation (L1 Bosnian/Croatian/Serbian, age 9)
nož za rezanje voća
'knife for cutting fruit'
voćni nož
fruit.ADJ SUFFIX-knife
'fruitknife'

(10) hybrid inflection and double marking (L1 Turkish, 9 years)
two dogen
ROOT.PL
'two dogs'
three yellow Mäuses
ROOT.UMLAUT.PL.PL
'three yellow mice'

These examples show the readiness to fill lexical gaps with items of the new language(s) (8), to use more convenient word formation processes which do not require the application of morphonological rules or syntactic processes, in brief compounding is the winner (9), and to mix

German and English morphology (free and bound morphemes) when needs be (10).

(11) lexical mixing (L1 Turkish, age 6)

*K 16 *Öğleden duruyom azcık, Gartena çıkyoz Gartendan sona çıktık zaman o zaman da şok oynuyoz.*

Garten~~a~~

garden.DAT

Garten-dan

garden.ABL

'At lunchtime I stay a little. We then go to the garden. After the garden, we went out, then we do things, we play in the garden a lot'.

(12) lexical mixing (L1 Turkish, age 10)

*K 38 Zeitimiz yok, saatimiz yok işte

Zeit~~imiz~~

time.POSS.1PL

'We have no time, that is no watch.'

The data below show a reduction of inflectional classes within the first language and lexical transfer from German to Bosnian, Croatian and Serbian:

(13) A kući govorim njemački.

*K45: A kući sprecham deutsch.

speak.1SG.PRES

'At home I speak German'.

(14) Bio sam na rođendanu.

*K05: Ja bio sa jedin Geburtstag.

sam-jedno

'I was at a birthday (party)'.

(15) moj prijatelj

*K05: jedan Freund od meine.

one-friend.SG.MASC-of-POSS.PL

'a friend of mine/one of my friends'

The following block lists frog-story data (Berman and Slobin, 1996; Strömqvist and Verhoeven, 2003) elicited from Turkish and Bosnian children (age-group 9–10 years):

(16) *K 68 *Sonradan bi sürü Frosch geldi o iki Froschun yanina. Kurbağa mi ismi?*

Frosch-un

frog-GEN

'Then many frogs joined the two frogs. Or is it frog?'

(17) *K 71 *Dişanda Mond var.*

dişan-da

outside.LOC
'Outside is the moon'.

(18) *K36: A Eule ide tamo, fliega doma.
And-owl-goes-there-fly.3SG.PRES-home.LOC
'And owl goes there, it flies home'.

(19) *K16: ... de ima puno onih Wespe-n-en, Biene-n to je ko oni tamo.
wasp.PL.PL-bee.PL.
'Where there are many wasps, bees that is like those over there'.

Examples like these give us once more to understand that neural and cognitive processes are invariably context- or function-dependent. As for the language internal processes they closely correspond to those to be observed in monolingual children, albeit at a different speed. Crossing linguistic borders creates idiosyncratic forms not to be encountered in any of the languages involved in the linguistic enterprise. What the two have in common is that they are short lived. Due the lack of reinforcement from the input they are ephemeral and have thus little chance of neural stabilization. "*The inevitable fate of variational morphological forms is their disappearance ... they were always unstable configurations as they were not properly fed by the input*." (Hohenberger, 2002: 124). Or to put it in more technical terms: perceptual information also serves to stabilize coordinated behaviour, as in the well-known anchoring effect in which specific, attended to perceptual inputs are selectively coupled to specific aspects of activity. From a neurocognitive perspective a novel task requires more attention than automated behaviour patterns. And as a consequence excitability and neural activity are increased in task conditions requiring more attention (see Kelso, 2003: 59).

6.2. Temporal Asynchrony in System Development

Linguistic systems do not develop simultaneously but at different times. This implies a changing sensitivity to input cues with different tasks being foregrounded at different times. Factors influencing the temporal asynchrony of development (within and across languages) are a changing sensitivity to language cues at different times, changing pattern preferences and system activities, the non-linear development of computational systems and the predominantly accumulative acquisition of the lexicon. What we have to consider are language-specific watersheds and hotspots influencing the speed and accuracy of development such as the reliance on morphological variation and word order (see Slobin, 1985 ff.).

To take the example of Turkish: word order is free except for the obligatory preverbal placement of unspecified direct objects. Turkish children are fast with the acquisition of agglutinative morphology. By age 6, Turkish

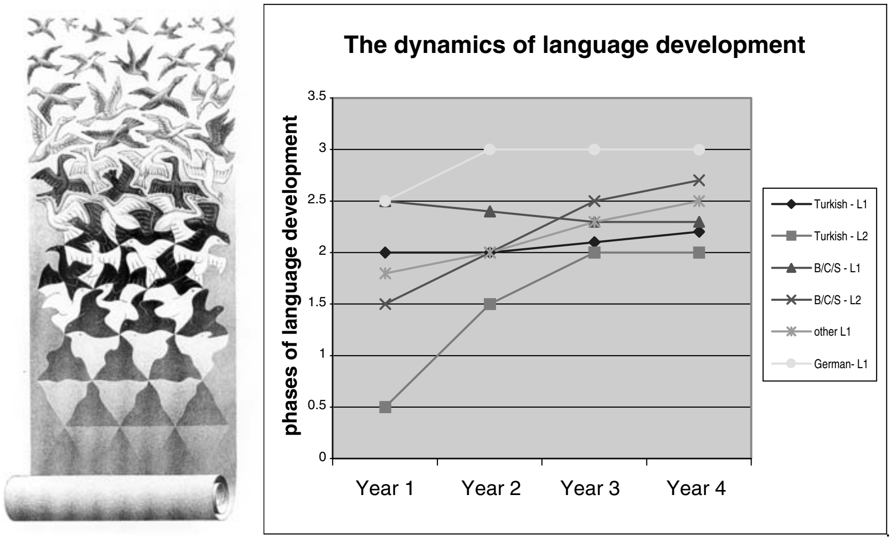

Figure 3. Dynamics of monolingual and bilingual language-development: The 4-year-trajectory of the first (L1) and the second language (L2).

children have acquired verbal inflection, plural, question formation and negation, but they still do have problems with genitive-possessive constructions (Boeschoten and Verhoeven, 1987). The data of our control study with monolingual children in Ankara corroborate these results.

Bilingual development as experienced in this long-term study can be summarized as follows: The developmental paths of mono- and bilingual children show a great similarity, apart from more or less intensive phases of code-mixing, the characteristic features of the individual developmental phases prove quite robust in the linguistic systems involved, mixed utterances cover up for lexical or structural gaps in the pertinent system, asynchronies in cross-linguistic development give evidence of separated systems (modules).

The growth-curves of the individual groups are shown in Figure 3. We combine the data once again with the Escher lithography to hint at the respective position within the chaotic itinerary~~ho~~listic processing close to the bottom, fine-grained towards the top.

The figure represents experimental data relating to the development of German and Turkish (Turkish~~L1~~, L2), German and Bosnian/Croatian/Serbian (B/C/S~~L1~~, L2), German as a first language (German~~L1~~), and the progress in German with children from different L1 groups (other L1) such as Arabic, Chinese and Hebrew which were not assessed in their mother tongue.

A problem to consider in this situation is the crossing of language dominance meaning that the hitherto first language cedes to the new language which receives more input and reinforcement. Alongside with the change of the cultural embedding a new system evolves which is grounded in the overall context of interlingua activities. In coordination dynamics loss of stability provides a selection mechanism in the form of bifurcations or phase transitions for the emergence of novel behavioural patterns. Fluctuations or variability are not 'errors' but rather a fundamental way for a system to test its own stability under the current circumstances (Kelso, 2003: 58). And to come to a close in a similar vein:

> Learning is not necessarily a smooth gradual process. Rather, depending on the strength of cooperative and competitive mechanisms, it may involve shifts in parameter space or highly non-linear, abrupt transitions (Eureka) (conclusion nr. 7, Kelso, 2003: 61).

7. CONCLUSION

Gravity and cognition have in common that both exist but cannot be got hold of. Gravity takes effect from $mass_1$ to $mass_2$, cognition is processed in the brain. The difference is that we have a formula for the first but not for the latter. Newton's law states that the force F of gravimetric attraction between two objects is proportional to the product of their masses (m, M) and inversely proportional (γ) to the square of the distance d between them: $F = \gamma mM/d^2$. There is nothing to equal that when it comes to the mind, but there is much to get theoretical about (how close we can get to formalizing show Kelso, 1995; Pribram, 1997; Diettrich; Aerts, Czachor and D'Hooghe; de Boer, this volume). With regard to language the inner form (not in the sense of Wilhelm von Humboldt) has been the object of sophisticated philosophical and linguistic investigations but to no avail as yet when it comes to mathematical laws. As for the computational systems (syntax and morphology) we owe much to Noam Chomsky for providing us with algorithms for the generation of sentences and morphological marking.

In their endeavour to locate us all cognitively and linguistically 'twixt ape and Plato' (to quote Keats) Hauser et al. (2002) call for substantial interdisciplinary cooperation of evolutionary biology, anthropology, psychology, linguistics and neuroscience. In view of all the findings reported on in this paper (and there are many more we could not place) they had better added EE to their list. In particular the second EE programme viz EET (evolutionary epistemology of theories) as envisaged by Bradie and Harms (2001) would be a great asset. As it were the above mentioned authors leave it to individual preference just where on that long evolutionary road we place ourselves. And there is not merely the urge to know more about ourselves but also the necessity to develop theoretically grounded means to protect the world we live in.

The data we cited from immigrant children should thus not merely be seen as an illustration of a bilingual chaotic itinerary but also as evidence for the influence of environmental conditions on language and linguistic behaviour. Changes in the evolutionary paths of languages in exile should also sharpen and uphold our awareness of the close links between mind, brain, language and culture (Wuketits, this volume, 1990, 2003). And to keep to our topic of interest Dan Sperber's (2001) research on mental modularity and cultural diversity needs mentioning here.

Our cross-disciplinary race touching upon evolution, selective theories, cognitive neuroscience, dynamic systems theory and the emergence of language(s) has shown that many of the questions posed by our forefathers could be solved by increasingly high-tech research. We all agree that humans have a language faculty. What is at issue is how specific it is. A widely accepted explanatory schema in linguistic theory expressed in acquisitional terms looks like that: *Primary Linguistic Data (PLD, Universal Grammar → Grammar)*. The arrow stands for a panoply of processes or operations, which could arise in a child endowed with certain genotypic properties and exposed to certain primary data. So far experimental work on language acquisition has not cast much light on the nature of the PLD. But we have learned about the PLD from historical work, examining the conditions under which different grammars have emerged over time (Lightfoot, 1999). And we no longer have to content ourselves with a definition of language learning as "*the process of determining the values of the parameters left unspecified by universal grammar, of setting the switches that make the network function*". (Chomsky, 1981: 134).

As for the relation between natural selection and Universal Grammar we had better hold it with Charles Darwin, who as a committed 'pluralist', never put excessive stock in natural selection but wisely invoked a panoply of evolutionary forces (Gould, 2002). In cognitive neuroscience the PLD come to the fore in the self-organization of patterns: "*The pattern of neural activity depends not only on the precise neuronal architecture but also, importantly, on its initial conditions*". (Buzsáki and Draguhn, 2004: 1928; Edelman, 1987).

In a synopsis of a paper on modularity it is opportune to state where we are with our endeavours to localize mental functions in the brain and with our ideas about compartmentalization. Firstly, most high-level cognitive functions cannot be justifiably associated with localized brain regions. The data reported in the literature are at times rather fragile and contradictory (Uttal, 2001). The mere list of cognitive processes associated with the frontal cortex in (Grafman et al., 1995) spans over seven pages. We may, however, safely assume that "*the cerebral cortex participates in brain work in awake human subjects by activating multiple cortical fields for each task*". (Roland et al., 1995: 784).

One of the reasons why, despite all the powerful imaging techniques, it is so difficult to put one's finger on a specific part of the brain is the multistability of cognition (Haken, 1996; 2003). Non-linear processes as postulated by dynamic systems theory obviously have their neural correlates in densely wired transcortical networks. Uttal (2001: 209) argues in a similar vein: "*Clearly, it is the complexity and nonlinearity of the interactions among the regions of the brain that is the source of the difficulty in this broader field of research*".

Non-linearity also seems to have this unsettling effect on genetic coding in the sense that, given the presence of non-linearity complicated behaviour can emerge from some relatively primitive arrangements (captured by Cavalli-Sforza's concept of family resemblance) in the language of the genes and the presently existing 6000 human languages (see Cavalli-Sforza et al., 1993). The rules of the game for the processes of biological evolution and those which produce new languages from a common ancestor are very likely to be the same (Duranti, 1997; Christiansen and Kirby, 2003).

Since large part of the paper deals with developmental trajectories we shall conclude with a report on the state-of-the-art of dynamic systems theory applied to the ontology of language. In the course of the past 15 years, various dynamical approaches have penetrated language acquisition research and accumulated evidence that (1) language is a non-linear dynamical system and (2) its development is poised between deterministic and indeterministic processes. Thus, as we have tried to show, language development does not take a linear path but comes in phases of intermittent turbulence, fluctuation and stability. Topics of immediate interest are:

(1) dynamic approaches to language development on different time scales, evolutionary, phylogenetic, ontogenetic, microgenetic
(2) non-linear phenomena in language acquisition: self-organization, self-similarity, bifurcation, bootstrapping, triggers, critical mass, emergence
(3) the interplay between language acquisition and neurocognitive development
(4) macro- and micro-variation, inter- and intra-individual differences.

The operating word in all these endeavours is emergentism, a term which relates to the position of an entity or rule in the evolutionary chain. Jay Gould (2003: 223) left us the following definition:

> [P]roperties that make their first appearance in a complex system as a consequence of non-additive interactions among components of the system are called *emergent*~~for~~ the obvious reason that they do not appear at any lower level (and have, therefore, 'emerged' or shown their face for the first time at the new level of complexity).

Our contribution to evolution or emergentism (MacWhinney, 1999) is a closer look at multilingual processes that operate across a time frame of 4 years. We have tried to show that immigrant children involved in the scaled acquisition and two or more languages provide good examples for the switching among attractors and temporal asynchrony.

As mentioned in the opening paragraph of this synopsis there are still some lacunae in our understanding of the relation of body and mind (Banich and Mack, 2003). Demands from prominent representatives of various disciplines pile up concerning the embodiment of cognition in future research (Wuketits, 1990, 2003; Pribram, 1997; Gazzaniga, 1997; Levi-Montalcini, 2004). A headstart in this direction has already been made by Wolfgang Tschacher and Jean-Pierre Dauwalder (2003: vii). They propagate *embodied cognition* meaning that "*the circular causality which synergetics conceptualises to be at the heart of self-organization permeates not only the mind, but also the world*". In order to achieve this embodiment of cognition we need an interdisciplinary platform that cuts across cognitive psychology, neuroscience, linguistics, computational modelling, physics, mathematics and philosophy~~and~~ EE to ask the right research questions and to keep the balance and the orientation.

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Against human nature

Tim Ingold

Department of Anthropology, University of Aberdeen, Aberdeen, Scotland, UK
tim.ingold@abdn.ac.uk

Abstract

Are cultural differences superimposed upon a universal human nature? The appeal to an essentialist concept of human nature is a defensive reaction to the legacy of racist science left by Darwin's argument in *The Descent of Man*. Humans are made to appear different in degree from their evolutionary antecedents by attributing the movement of history to a process of culture that differs in kind from the biological process of evolution. The specifications of evolved human nature are supposed to lie in the genes. However, human capacities are not genetically specified but emerge within processes of ontogenetic development. Moreover the circumstances of development are continually shaped through human activity. There is consequently no human nature that has escaped the current of history.

1. INTRODUCTION

There is a fundamental contradiction at the heart of current evolutionary thinking. Natural science, including the science of evolutionary biology, has developed in the West as an inquiry into the objective properties of things. Thus the applicability of evolutionary biology to humans depends upon our accepting that they are things as well. Yet *they are us*, and were we but things, objects of nature, how could we know ourselves for what we are? Paradoxically, if organisms are living things, then to know ourselves as organisms we must be *more* that organisms. We must be both objects inside the world of nature and subjects outside of it, things and persons, at one and the same time. Thus even as science insists that the human is just another biological species, the very institution of science~~an~~d its claims to deliver an authoritative account of how nature really works~~re~~sts on the idea that humans have been raised by a process of culture or civilisation, without parallel in the history of life, onto a level of being over and above the purely biophysical. This is why science continues to appeal to a notion of essential humanity in the name of

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a theory, of variation under natural selection, that denies its very existence. To resolve the contradiction we need nothing less that a new way of thinking about human evolution: one that enables us to understand the evolutionary process from within, recognising that we ourselves are no more able to watch from the sidelines as are creatures of any other kind, and that like them, we participate with the whole of our being in the continuum of organic life. And the first step in establishing this way of thinking is to revisit the hoary old question of human nature. That will be my task here.

2. A TAIL OF HUMAN BEINGS

People differ the world over, and the study of these differences has always been the special province of anthropology. But is difference superimposed upon a baseline of characteristics that all human beings have in common? Is there such a thing as a universal human nature? In this article I want to put into question what many of us, I believe, take for granted. You may think it obvious that human nature exists; I am going to suggest that it does not. This may seem an odd conclusion to reach; after all, we surely know another human being when we see one. People may differ a lot, but not so much that we nowadays have any problem in drawing the line between humans and non-humans. But less than three centuries ago, matters were much less certain. So let us start by going back to that time~~a ti~~me when people in Europe were not yet aware of the full range of human variation.

By the early 18th century, European traders and explorers were beginning to reach regions of the globe they had never visited before, such as parts of Africa and the East Indies. Reports were coming back, not only of strange and exotic tribes but also of creatures that, though hairy all over and sometimes even sporting tails, and though apparently lacking the gift of language, nevertheless bore a closer resemblance to human beings than anything previously encountered. Were these creatures, then, human or not? Reproduced in Figure 1 is a picture, dating from 1760, which was drawn on the basis of information derived from such reports. The picture has an interesting history. It comes from a treatise by the great Swedish naturalist Carolus Linnaeus. It was Linnaeus, of course, who was responsible for creating the system for classifying plants and animals, by genus and species, that is still in general use today. And it was he, too, who took the bold and momentous step~~co~~nsidered outrageous by many of his contemporaries~~of~~ placing human beings within the same overall scheme of classification, under the genus *Homo*, alongside all other members of the animal kingdom. This is not to say that Linnaeus thought that man was a ‘mere animal’, for indeed he was to be distinguished in a way quite different from that in which other animals are distinguished from

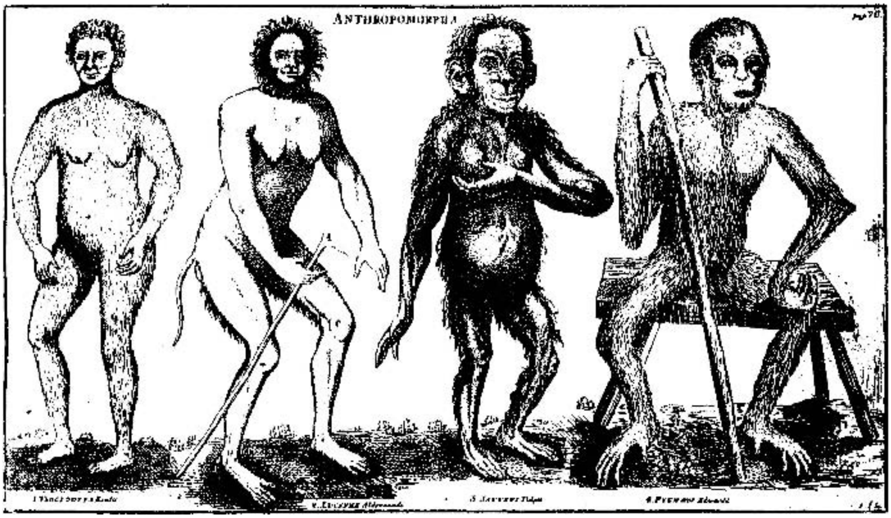

Figure 1. ‘Anthropomorpha’, from C. E. Hoppius, *Amoenitates academicae* (Linné), Erlangae 1760. Lucifer is the second figure from the left.

each other. I shall return to this point in a moment. For the present let us look more closely at this picture. Actually drawn by one of Linnaeus’s pupils, by the name of Hoppius, it bears the title *Anthropomorpha* (literally ‘human forms’), and shows four characters by the names of Troglodytes, Lucifer, Satyrus and Pygmaeus. The question that confronted Linnaeus and his contemporaries was this: which of these, if any, were human, or could be grouped under the genus *Homo*?

One of those who read Linnaeus’s account was the Scottish judge James Burnet, otherwise known as Lord Monboddo. A scholar of considerable repute, Monboddo published between 1773 and 1792 a massive six-volume work, entitled *On the origin and progress of language*, and in the very first volume he referred to our picture. He was particularly concerned with Lucifer, the one with a tail. Could a human being, Monboddo wondered, possibly have a tail? Anticipating that his readers would find such a thing incredible, he reminded them that they should not be bound by their own, fixed ideas of what humans were like. Just because they had never met humans with tails did not mean that such could not exist. If some humans have white skins and others black, is it not just as possible that some have tails whereas others do not? It is no good merely saying ‘humans aren’t like that’, Monboddo argued, for that would be to impose our own preconceived notions about what kind of thing a human being is. It is in the nature of all animal kinds, he thought, that they are not uniform and immutable but geographically and historically variable, and in this the human should be no exception. Having carefully weighed up the evidence, Monboddo came to the conclusion that Lucifer was indeed a human being (Reynolds, 1981: 40–42).

Of course in hindsight we know that Monboddo was wrong. We can now recognise the figures in the picture as rather fanciful depictions of the great apes, though since even apes lack tails, Lucifer seems to be a kind of hybrid between an ape and a monkey. Could it not be, nevertheless, that Monboddo was wrong for the right reasons? My argument in this article will be that Monboddo's warnings against projecting a Eurocentric construction of human nature upon the infinitely contoured and ever-changing terrain of human variation are as relevant to us today as they were in his time. We continue to seek some universal and changeless bedrock for our common humanity, but it terms that overtly celebrate the values and ideals of Western modernity. What is all the more remarkable is that we do so in the name of a biology remodelled on the Darwinian idea that the characteristics of species evolve through a process of variation under natural selection, even though~~as~~ we shall see shortly~~thi~~s biology teaches us that for *no* species does there exist an essence of its kind. To find the reasons why we are so compulsively driven to search for the essence of humanity, we have to dig deeper into our own tradition of thought, a tradition that is far older than Darwin and that continues to influence present-day thinking to an extent that we are rarely prepared to acknowledge. So to pick up the story, let me return to Linnaeus, and to the problems he was having in his attempts to fit the genus he had christened *Homo* within his overall system of classification.

3. THE ASCENT OF REASON

Remember that at the time Linnaeus was writing, in the middle of the 18th century, information about apes consisted largely of travellers' tales, not all of them entirely trustworthy. With the limited factual evidence available to him, Linnaeus found it rather difficult to discover any anatomical features that would reliably separate humans from apes. The distinction, he surmised was of a different order, to be grasped by introspection rather than observation: *Nosce te ipsum*, 'know for yourself'. Do you ask how a human being differs from an ape? The answer, says Linnaeus, lies in the very fact that you ask the question. It is not one that apes ask of themselves. Apes and humans may look alike, but only humans are able to reflect upon the kind of beings they are. This, thought Linnaeus, is because they have been endowed, by their Creator, not only with a functioning body but also with the gift of intellect or reason, that is with a *mind*, thanks to which humankind is equipped to exercise control and domination over the rest of nature. There are no scientists among the apes.

Like every other major European thinker of that period, Linnaeus firmly believed that every species had come into existence for all time through an act of divine creation. And he thought that for every species there was an essential form, a basic architecture or ground-plan, to which all individuals of the species conformed to greater or lesser degree. It is often to this kind of basic architecture that we refer when we speak of the ‘nature’ of a thing, or class of things. Thus each species was supposed to have its particular nature, regardless of idiosyncratic differences among the individuals that make it up. And in this the human was held to be no exception. The notion of human nature has its roots in this ancient way of thinking. Philosophers call it ‘essentialism’: that is, the doctrine that for every class of things there exists a fixed, essential form or constitution.

Now modern biology has~~at~~ least in theory~~re~~jected essentialism, along with the idea of the divine creation of species. In the history of science, the figure who is generally credited with having brought about this revolution in thinking was, of course, Charles Darwin. In his epoch-making work *The Origin of Species*, published in 1859, Darwin had argued that every species is just a collection of individuals, each minutely different from every other. As the variations that underlie these differences are transmitted to offspring, those that are favourable to the reproduction of their carriers, under prevailing environmental conditions, accumulate along certain lines of descent, while those that are less favourable gradually disappear. This is what Darwin called natural selection. Through natural selection, species continually evolve. One line of descent may split up into two or more diverging lines, yielding several distinct species (as, for example, the lines leading to chimpanzees and humans). The vast majority of lines, however, have ultimately come to the dead end of extinction.

Ever since Darwin, the basis for biological classification into species, genera and so on has been *genealogical*. That is to say, individuals are grouped into the same class on the grounds not of their formal approximation to a basic template or design, but of their descent from a common ancestor. It is characteristic of living things, as distinct~~sayfro~~m inorganic crystals, that each one is unique, differing, albeit minutely, from each and every other along manifold axes of variation (Medawar, 1957). Grains of salt all have the same molecular composition, of sodium chloride, and in this respect comprise what is technically called a ‘natural kind’~~a c~~lass of objects united by the fact that they all have some essential attribute in common. But barring identical twins and natural or artificial clones, no living organism, in its genetic constitution, is quite the same as any other. Individuals of a species may share a family resemblance, but there is no single thing common to all of them. Were it not for this intrinsic variability, natural selection could not occur. There is no formal, species-specific ground-plan hovering in the background, immune from time and change.

Now if this is true of species in general, then it must be true of the human species in particular. Accordingly, what connects us as members of a single species (*Homo sapiens*) is not our possession of a common nature, but our descent from a single ancestral population. In *The Origin of Species*, however, Darwin had virtually nothing to say about human evolution. Indeed, he had nothing really to say about evolution at all, for the word appears only once in the entire book~~in~~the very last sentence!Instead, he spoke of 'descent with modification'. Only subsequently, largely as a result of a colossal mistake perpetrated by the philosopher Herbert Spencer and compounded by generations of biologists ever since, was the concept of evolution substituted for that of descent with modification (Ingold, 1998: 80–81). Throughout the *Origin*, Darwin pictures himself as a spectator, watching the panorama of nature unfold before his eyes. And it was in this original sense of unfolding that he testified to a process of evolution. *"There is grandeur in this view of life"*, Darwin wrote in the closing sentence of his book~~in~~the realisation that *"while this planet has gone cycling on according to the fixed laws of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved"* (Darwin, 1872: 403).

But this is not a view of life available to non-human animals. They are condemned to live more or less *within* the world of nature, whereas Darwin could write as though he himself were *above* it, and could look at it in the manner of a spectacle. Yet Darwin was a human being. How was it, then, that human beings~~or~~at least the more civilised among them~~co~~uld reach such an exalted or transcendent position vis-à-vis the rest of nature? It was in a later book, *The Descent of Man*, published in 1871, that Darwin set out to answer this question. Where *The Origin of Species* was, as it were, a view from the summit, *The Descent of Man* was an account of the climb (Ingold, 1986: 49). But it was a very different kind of book from *The Origin.* In an idiom shot through with the moral attitudes of his day, Darwin here attempted to establish a single scale, running all the way from the most primitive of animals to the most advanced of humans, along which could be charted the rise of reason or intellect, and its gradual triumph over the shackles of instinct. Where Darwin differed from many (but by no means all) of his predecessors was in both attributing powers of reasoning to subhuman animals and recognising the powerful sway of instinct even on the behaviour of human beings. The beginnings of reason, he argued, could be found far down in the scale of nature, but only with the emergence of humanity did it begin to gain the upper hand.

In short for Darwin and his many followers, the evolution of species *in* nature was also an evolution *out* of it, in so far as it progressively liberated the mind from the promptings of innate disposition. Ever since, Western science has cleaved strongly to the view that humans differ from other animals in degree rather than kind. Darwin, it is said, finally showed us that the idea of an absolute

Rubicon separating the human species from the rest of the animal kingdom is a myth. He did not, however, dispense with the dichotomy between reason and nature, or between intelligence and instinct; rather his whole argument was couched in terms of it. Recall that for Linnaeus it was man's possession of the faculty of reason that allowed him to rise above, and exercise dominion over, the world of nature. Darwin concurred: *"Of the high importance of the intellectual faculties there can be no doubt, for man mainly owes to them his predominant position in the world"* (1874: 196). His point, however, was simply that the possession of reason—or the lack of it—is not an all or nothing affair distinguishing all humans from all non-humans. In evolutionary terms, Darwin thought, reason advanced by a gradual, if accelerating ascent, and not by a quantum leap. *"We must admit"*, he observed, *"that there is a much wider interval in mental power between one of the lowest fishes . . . and one of the higher apes, than between an ape and a man; yet this interval is filled by numberless gradations"* (Darwin, 1874: 99).

4. THE SCIENTIST AND THE SAVAGE

Now the idea that no radical break separates the human species from the rest of the animal kingdom is in fact an ancient one, going back to the classical doctrine that all creatures can be placed on a single scale of nature, or what was called the 'Great Chain of Being', connecting the lowest to the highest forms of life in an unbroken sequence (Lovejoy, 1936). Every step along the chain was conceived as a gradual one or, as the saying went, 'nature never makes leaps'. Initially the idea was that each species was immutably fixed in place, from the moment of Creation, at a particular position on the chain, such that not a single position remained unfilled. It was the French naturalist and originator of the term 'biology', Jean Baptiste Lamarck, writing in the early decades of 19th century, who set the chain in motion. He thought of it as a kind of escalator, on which organisms are continually working their way up the scale of nature, while new ones arise at the bottom to make their way up in their turn. Thus the monkey was on its way to becoming an ape; the ape on its way to becoming a human. Darwin, in his theory of evolution by natural selection, replaced the image of the single chain with that of a branching tree, but the idea of gradual change remained (Ingold, 1986: 5–9). According to the view of the evolution of our species that you will find in any modern textbook, our ancestors became human by degrees, over countless generations. An unbroken sequence of forms is supposed to link the apes of some five million years ago, from which both human beings and chimpanzees are descended, through the earliest hominid creatures of two million years ago, to people like you and me—certified humans of the species *Homo sapiens*.

As an account of human biological evolution that may be all very well, but what about human history? Theorists of the 18th century tended to think of human history as the story of man's rise from primitive savagery to modern science and civilisation. These thinkers belonged to the movement in European thought known as the Enlightenment, and the idea that human reason would rise and eventually triumph over the brute forces of nature was the centrepiece of their philosophy. Yet they were also committed to the doctrine that all human beings, in all places and times, share a common set of basic intellectual capacities, and in that sense may be considered equal. This doctrine was known as that of the 'psychic unity of mankind'. Differences in levels of civilisation were attributed to the unequal *development* of these common capacities. It was as though allegedly primitive peoples were at an earlier stage in the pursuit of a core curriculum common to humankind as a whole. In short, for these 18th century thinkers, human beings differed in *degree* from other creatures with regard to their anatomical form, but nevertheless were distinguished in *kind* from the rest of the animal kingdom insofar as they had been endowed with minds~~tha~~t is with the capacities of reason, imagination and language— which could undergo their own historical development within the framework of a constant bodily form (Bock, 1980: 169; Ingold, 1986: 58).

The immediate impact of Darwin's theory of human evolution, as set out in *The Descent of Man*, was to subvert this distinction. The scientist and the savage, Darwin insisted, are separated not by the differential development of intellectual capacities common to both, but by a difference of capacity comparable to that which separates the savage from the ape. *"Differences of this kind between the highest men of the highest races and the lowest savages, are connected by the finest gradations"* (Darwin, 1874: 99). And these differences were, in turn, a function of the gradual improvement of a bodily organ, the brain (ibid: 81–82). Throughout human history, the advance of civilisation was supposed to march hand-in-hand with the evolution of the brain, and with it of the intellectual and moral faculties, through a process of natural selection in which *"tribes have supplanted other tribes"*~~as~~ even now *"civilised nations are everywhere supplanting barbarous nations"*~~the~~ victorious groups always including the larger proportion of *"well-endowed men"* (ibid: 197). In this process the hapless savage, cast in the role of the vanquished in the struggle for existence, was sooner or later destined for extinction.

Darwin's commitment, in *The Descent of Man*, to an imperialist doctrine of progress according to which the morally and intellectually well-endowed are bound to supplant their inferiors, not only ran counter to the whole argument of *The Origin of Species*, but was also deeply racist. Whereas in the *Origin* Darwin had shown that the mechanism of natural selection always operates in such a way as to make species better adapted to their particular environmental conditions of life, in the *Descent* he argued that it would inevitably bring about absolute advance along a single, universal scale—from the lowest of animals to the highest of men (Darwin, 1874: 194)—regardless of environmental conditions, leading from instinct to intelligence, and reaching its ultimate conclusion in modern European civilisation. And in bringing the rise of science and civilisation within the compass of the same evolutionary process that had made humans out of apes, and apes out of creatures lower in the scale, Darwin was forced to attribute what he saw as the ascendancy of reason to hereditary endowment. For the theory to work, there had to be significant differences in such endowment between 'tribes' or 'nations'—or between what we might today call populations.

Conversely, however, if there were no such differences then the theory could not work, as Alfred Russell Wallace, the co-discoverer of natural selection, found to his cost. Having the advantage of a much greater familiarity and sympathy with the ways of 'primitive' people than Darwin ever had, Wallace was most impressed by the wealth and diversity of their cultural achievements. These achievements, he felt sure, were the work of superior brains. But how could natural selection have produced brains apparently capable of so much more than was actually required under the simple conditions of primitive life? *"Natural selection"*, Wallace wrote, *"could only have endowed savage man with a brain a little superior to that of an ape, whereas he actually possesses one very little inferior to that of a philosopher"* (Wallace, 1870: 356). His notorious conclusion, to Darwin's dismay, was that only a Creator would come to think of preparing the savage for civilisation in advance of his achieving it. For this apparent capitulation to creationism, subsequent generations of evolutionists would unfairly banish Wallace to the sidelines of the history of their science.

For in his estimation of the intellectual capacities of so-called 'savages', Wallace was right and Darwin was wrong. The term 'savage' was generally applied by 19th century anthropologists and their predecessors to people who lived by hunting and gathering. We now recognise that the brains of hunter-gatherers are just as good, and just as capable of handling complex and sophisticated ideas, as the brains of Western scientists and philosophers. Nevertheless racist notions about the innate mental superiority of White European colonisers over indigenous peoples were remarkably persistent in biological anthropology. We should not forget that the idea of eugenics—that is, of bringing about an overall improvement in human capacities through a deliberate policy of breeding—enjoyed a certain respectability in Western scientific circles right up until the time of the Second World War. It was the War, and above all the atrocities of the Holocaust, that finally laid that idea to rest. What was self-evident to Darwin and most of his contemporaries—namely that human populations differed in their innate intellectual capacities on a scale from the primitive to the civilised—is no longer acceptable today. Darwin's view that the difference between the savage and the civilised man was one of brain-power has given way in mainstream science to a strong moral and ethical commitment to the idea that *all* humans~~pas~~t, present and future~~are~~ equally endowed, at least so far as their moral and intellectual faculties are concerned. *"All human beings"*, as Article 1 of the Universal Declaration of Human Rights states, *"are endowed with reason and conscience"*.

5. HUMAN NATURE AND HISTORY

But this left the Darwinians with a problem on their hands. How was the doctrine of evolutionary continuity to be reconciled with the new-found commitment to universal human rights? If all humans are alike in their possession of reason and moral conscience~~if,~~ in other words, all humans are the kinds of beings who, according to Western juridical precepts, can exercise rights and responsibilities~~the~~n they must differ in kind from all other beings which cannot. And somewhere along the line, our ancestors must have made a breakthrough from one condition to the other, from nature to humanity.

Faced with this problem, there was only one way for modern science to go~~tha~~t is, back to the 18th century. Indeed the majority of contemporary commentators on human evolution appear to be vigorously, if unwittingly, reproducing the 18th century paradigm in all its essentials. One process, of evolution, leads from our ape-like ancestors to human beings that are recognisably of the same kind as ourselves; another process, of culture or history, leads from humanity's primitive past to modern science and civilisation. Taken together, these two axes of change~~the~~ one evolutionary, the other historical~~est~~ablish by their intersection a unique point of origin, without precedent in the evolution of life, at which our ancestors are deemed to have crossed the threshold of true humanity and to have embarked on the course of history. And standing at the threshold, at the point of origin when history diverges from evolution, and culture from biology, is the figure of the primitive hunter-gatherer, today's equivalent of the 18th century's savage.

It is a remarkable fact that whenever scientists are concerned to stress the evolutionary continuity between apes and humans, the humans are almost always portrayed as ancient hunter-gatherers (or if contemporary hunter-gatherers are taken as examples, they are commonly regarded as cultural fossils, frozen in time at the starting point of history). According to a now widely accepted scenario, it was under conditions of life as hunter-gatherers, hundreds of thousands of years ago in the era that geologists and palaeontologists call the Pleistocene, that the biological and psychological capacities evolved—language, symbolic intelligence, bipedalism, toolmaking, male-female pair-bonding and so on~~tha~~t are supposed to have made us human. Once established they have remained with us, as a legacy from our evolutionary past.

Thus every one of us is said to carry, as a fundamental part of our biopsychological make-up, a set of capacities and dispositions that originally arose as adaptations to the requirements of hunting and gathering in Pleistocene environments. As the distinguished archaeologist J. Desmond Clark put it, in a lecture delivered in 1990, *"the behavioural complexes of ancestral hunters lie deep within the psycho-social patterning of the nervous system of all humans and, when better understood, these can help to show how we came to be what we are today"* (Clark, 1990: 13). The doctrine of psychic unity, it seems, was right after all, or as John Tooby and Leda Cosmides declare in their manifesto for the brave new science of evolutionary psychology, *"the psychic unity of mankind is genuine and not just an ideological fiction"* (Tooby and Cosmides, 1992: 79). This unity, they believe, lies in the *"evolved architecture of the human mind"*, in other words in human nature.

Following this line of argument, so far as their evolved capacities are concerned there should be little or nothing to distinguish today's scientists and engineers from the hunter-gatherers of 50,000 or even 100,000 years ago. What makes them different, apparently, is a separate process of history, or what many have taken to calling cultural (as opposed to biological) evolution. But the movement of culture is said to have left our basic biological constitution virtually unaffected, hardly changed from what it was in the Stone Age. *"History"*, state David and Ann James Premack, *"is a sequence of changes through which a species passes while remaining biologically stable"*~~an~~d only humans have it (Premack and Premack, 1994: 350–351). Yet this very distinction implies that at some point in the past, history must have 'lifted off' from a baseline of evolved human capabilities. Short of supposing some kind of unfathomable quantum leap or~~wi~~th Wallace~~in~~voking the miraculous intervention of a Creator, there seems to be no alternative but to imagine a historical trajectory that rises inexorably from a point of emergence, gathering pace as it does so, leaving the biological constitution of the organism, confined to the slow lane of evolutionary change, far behind.

Indeed this kind of picture, first elaborated in a celebrated paper by the anthropologist Alfred Kroeber and published in 1917 under the title of *The Superorganic* (Kroeber, 1952), has been invoked on countless occasions ever since. But it raises a host of awkward questions. If human history has a point of origin, what could it mean to have been living close to that point, or even at the crucial moment of transition itself? Were such people semi-cultural, gearing up for history? How can one conceivably distinguish those actions and events that carried forward the movement of human history from those that set it in motion in the first place? Indeed it is hard not to see, in the image of our hunter-gatherer ancestors looking out upon the dawn of history, the reflection of a decidedly modern political rhetoric. And it has set prehistorians on a frantic and much publicised search for the time and place of emergence of what are euphemistically called ‘anatomically modern humans’—that is, people who were *biologically* indistinguishable from ourselves even though *culturally* still at the starting block. Their appearance is said to mark nothing less than the ‘human revolution’ (Mellars and Stringer, 1989).

So after all that, the paradox remains. Short of reverting to the racially stratified scenario of Darwin, with its populations of more or less well-endowed men, the only way in which humans can be made to appear different in degree, not kind, from their evolutionary antecedents is by attributing the movement of history to a process of culture that differs in kind, not degree, from the process of biological evolution!The division between nature and reason is still there, but is now shifted onto that between the exotic hunter-gatherer and the Western scientist, the former epitomising a view of humanity in the state of nature, the latter epitomising the triumph of human reason *over* nature. Even today, there are scholars—many of whom would call themselves scientists—who assert that through the study of hunter-gatherers, whether ancient or modern, we should gain a window on evolved human nature which is obscured, in the study of societies of other kinds, through the subsequent accretions of culture and history (Clark, 1990).

Where, then, does this human nature lie? How come that these capacities with which we are all supposed to be innately endowed have been faithfully handed down, over tens of thousands of years, apparently immune to the vagaries of history? For most contemporary students of human evolution the answer is simple: because they are in the genes.

6. GENES AND DEVELOPMENT

Now this response merely evades the issue, and is really no answer at all. Let me explain why. Genes consist of sections of an immensely long molecule called DNA, which is found in the nucleus of every cell in the body. Of this genetic material, about 80 per cent—so-called ‘junk DNA’—is entirely inconsequential. The genes comprising the remaining 20 per cent, however, play a crucial role in regulating the manufacture of proteins, which are the principal materials from which organisms are made. What these genes do not do, however, is contain a programme or blueprint for building an organism of a certain kind. The notion of the genetic blueprint is fundamentally misleading, for the simple reason that organisms are not built like machines, on the basis of pre-existing design specifications. Rather they *grow*, a process technically known as ontogenetic development. This applies as well to human beings as to organisms of any other species. Thus you cannot simply point to the DNA in the cell nucleus and say: ‘There is a capacity for such-and-such’.

It is make-believe to think that lengths of DNA can turn themselves into 'innate capacities', whether of body or mind, before this process has even got underway. Whatever capacities people might have, in the form of skills, motivations, dispositions and sensibilities, they are generated in the course of development. And at whatever stage in the life-cycle we may choose to identify a particular capacity—even at birth—a history of development already lies behind it (Dent, 1990: 694).

More importantly, people do not live their lives in a vacuum but in a world where they are surrounded by other people, objects and places, together making up what is usually known as the environment. Growing up in an environment largely shaped through the activities of their predecessors, human beings play their part, through their intentional activities, in fashioning the conditions of development for their successors. This is what we call history. It is my contention that there is no human nature lurking inside us that has somehow escaped the current of history. Of course we all carry our complement of genes, but these do not set us up with a constitution in place, ready to interact with the outside world. Sensible biologists have long recognised that the dichotomy between nature and nurture is obsolete. But it is not enough to say, instead, that we are products of nature *and* nurture, as though these were separate things—genes on the one hand, environment on the other—that then interact to form the organism. For genes do *not* interact with the environment (Keller, 2001). As Daniel Lehrman pointed out many years ago, the interactions from which the development of an organism proceeds are not between genes and environment but between *organism* and environment, and the organism is not a constant but the continually changing embodiment of a whole history of previous interactions that have shaped its life course to that point (Lehrman, 1953: 345). Nor is the environment a constant for it, too, exists only in relation to the organisms that inhabit it, and embodies a history of interactions with them.

If genes interact with anything, it is with other constituents of the cell, which interacts with other cells in the organism, which interacts with other organisms in the world. It is out of this multilayered process that the capacities of living beings emerge. In other words, these capacities are products of the whole *developmental system* comprised by the genome in the cells of the organism in its environment (Lewontin, 1983; Oyama, 1985). There is no good reason why we should home in on the genes, as the locus of the nature of the organism, rather than any other of the myriad components of the system (Griffiths and Gray, 1994). The fact that we nevertheless continue to do this, apparently with the full backing and authority of science, is due to a fundamental misunderstanding about the nature of information. This point is so crucial that it calls for a brief digression.

7. THE IMAGINARY GENOTYPE

Strictly speaking, as we have seen, the gene is simply a particular segment of the DNA molecule. However, evolutionary biologists frequently refer to the gene in another sense, as carrying information that encodes a particular trait or character. This is the so-called 'Mendelian gene' (Dunbar, 1994: 762). Taken together these Mendelian genes add up to a kind of character specification for the organism as a whole, technically known as its *genotype*. How came it, then, that lengths of DNA in the genome came to be identified, under the same concept of the gene, with information coding for particular traits making up the genotype? In the commonly understood, vernacular sense, information refers to the semantic content of messages transmitted from senders to recipients. It is the meaning attached by the sender to the message, intended for its recipient. But it was not by extension from this vernacular usage that the concept of information entered biology. Rather, its source lay in the theory of information as it had been developed in the 1940s by Norbert Wiener, John von Neumann and Claude Shannon. In the specialised sense employed by information theorists, 'information' has no semantic value whatever; it does not *mean* anything. Information, for them, meant simply those differences, in the input to a system, that make a difference in terms of outcome.

This point was entirely lost on the molecular biologists, who, having realised that the DNA molecule could be regarded as a form of digital information in the technical, information-theoretic sense, immediately jumped to the conclusion that it therefore qualified as a *code* with a specific semantic content. The point was not lost, however, on the information theorists themselves, who repeatedly warned against the conflation of the technical sense of information with its vernacular counterpart and looked on in dismay as the scriptural metaphors of message, language, text and so forth became entrenched in a biology that had become seemingly intoxicated with the idea of DNA as a 'book of life'. Since then, and especially with all the hype surrounding the human genome project, these metaphors have become more prevalent than ever, and the original confusion upon which they rest has virtually disappeared from view (Kay, 1998).

In truth, the DNA of the genome does not encode anything: there is no 'message'. Placed within a cellular context, DNA undergoes a process of replication, but it is an illusion to suppose that the replication of this genetic material is tantamount to a replication of a character specification for the organism. The only 'reading' of the DNA is the process of ontogenetic development itself, whose outcome is the manifest form of the organism—otherwise known as its *phenotype*. Or to put it another way, the genome can be regarded as a carrier of coded information only if the outcome of the developmental process is presupposed. What, then becomes of the genotype? Where is it? Does it exist at all?

By definition, and as opposed to the phenotype, the traits comprising the genotype are assumed to be wholly independent of developmental context, and to be already in place at the point of inauguration of a new life-cycle. But how have they come to be placed there? Not, evidently, by the mechanism of genetic replication. What has happened, it seems, is that in their effort to prove that the properties of organisms have evolved by natural selection, biologists have sought to redescribe the characteristics of these organisms in a way that factors out all variation ostensibly due to environmental experience. That is, they have sought to produce, for each, an abstract, context-independent specification. This abstraction is then 'read in' to the genome~~as~~ if it had a concrete presence in there~~so~~ that development itself can be seen as a 'reading off', under particular environmental conditions, of a pre-existing specification. The circularity of this argument needs no further elaboration, and is one reason, of course, why it has proved so hard to refute.

Nothing better illustrates this tendency to transpose, into the organism, a set of abstract specifications derived from our external observation of them, than the fate of the concept of biology itself. Referring initially to the procedures involved in the scientific study of organic forms, 'biology' has come to be seen as a set of directives~~lite~~rally a *bio-logos*~~su~~pposedly residing in the organisms themselves, and orchestrating their construction. For any particular organism this bio-logos is, of course, its genotype. Herein lies the explanation for the commonplace, though highly misleading identification of 'biology' with genetics. The very notion of biology has come to stand in for the belief that at the heart of every organism there lies an essential specification~~a~~— nature~~tha~~t is fixed from the start and that remains unchanged throughout its lifetime. To be sure, this specification is taken to be open-ended, affording scope for the developmental outcome to be conditioned by environmental circumstances. But understood in this sense~~as~~ components of a conditional specification~~the~~ genes are, as I have shown, entirely imaginary.

Now what applies to organisms in general must surely apply in particular to those organisms we call 'human'. The human genotype, in short, is a fabrication of the modern scientific imagination. This does not mean, of course, that a human being can be anything you please. But it *does* mean that there is no way of describing what human beings *are* independently of the manifold historical and environmental circumstances in which they *become*~~in~~ which they grow up and live out their lives. As we all know, these are extremely variable. But what are the implications of this view for our understanding of culture and history?

8. FROM WALKING TO CELLO-PLAYING

In order to answer this question, perhaps it will help first to spell out what I take to be a rather orthodox view of the relation between human nature and culture. According to this view there are two kinds of inheritance in human populations, which run in parallel. One is said to be ‘biological’, the other ‘cultural’. Biological inheritance works through the transmission of genetic information encoded in the DNA; cultural inheritance is more or less independent of genetic transmission, and takes place through a process of learning. The first provides us with the essentials of human nature; the second adds on a superorganic or ‘non-biological’ component. Consider a couple of apparently uncontroversial examples. I can walk and I can play the cello. Bipedal locomotion is generally regarded as a species attribute of *Homo sapiens*, an integral part of our evolved human nature. Cello playing, by contrast, is surely a cultural skill with a very specific background in the European musical tradition.

But human beings are not born walking, nor do they all walk in the same way. There is, as the anthropologist Marcel Mauss observed in his famous essay of 1938 on *Techniques of the Body*, no *natural* way of walking (Mauss, 1979: 102). In Japan, at least traditionally, it was conventional to walk ‘from the knees’, in what looks to us like a rather shuffling gait, but one that actually makes very good sense when your footwear is sandals, and when you have to walk on very steep terrain, as is common in the Japanese countryside, especially when carrying heavy loads slung from either end of a long, supple pole balanced across one shoulder. To the European, however, this looks most ungainly. We are taught from an early age of the virtues of upright posture, and baby walkers are used to get your child standing up at as early an age as possible (as a device, the baby walker is not new, but has been around for centuries). We are taught to walk from the hips, and not from the knees, while keeping the legs as straight as possible. And our carrying devices, from rucksacks to suitcases, are designed with this posture in mind (Kawada, n.d.).

Are these inflections of walking non-genetic or superorganic supplements added on to a universal capacity for bipedal locomotion that has already been imparted to the human body by the genes? Surely not. For walking is not a compound of pre-existing and add-on components, but a skill that is gradually acquired mainly but not exclusively in the first few years of life, and incorporated into the *modus operandi* of the human organism through practice and training within an environment that includes skilled caregivers, along with a variety of supporting objects and a certain terrain (Ingold, 2000: 375). It is, in that respect, the outcome of a process of development. And because people encounter different developmental circumstances, they walk in different ways. As Esther Thelen and her colleagues have shown, in a series of studies of infant motor development, there is no *"essence of walking that can be isolated from the real-time performance of the action itself"* (Thelen, 1995: 83). But is it any different with my ability to play the cello? This, too, is a bodily skill, likewise established through practice. Of course I had a teacher, and we may say colloquially that my teacher passed on his skills to me. What he did not do, however, was *transmit* them to me, as advocates of the orthodox view would say, by *non-genetic means*. That is, he did not send me abstract, decontextualised messages, encoded in symbolic media, specifying rules of play which I had then to execute in my performance. Rather he would place my hands around the bow, and my fingers on the fingerboard, so that I could experience for myself the relation between the movement of my right arm and the vibrations of the strings, and between the muscular tensions in the left hand and the resulting intervals of pitch. My ability to play the cello was not transmitted to me any more than was my ability to walk. Rather, I grew into it.

Indeed the metaphor of transmission, whether attributed to genes or culture, is deeply misleading. For the growth of practical knowledge in the life history of a person is a result not of information transmission but of guided rediscovery. By this I mean that in each successive generation, novices learn through being placed in situations in which, faced with certain tasks, they are *shown* what to do and what to look or listen out for, under the tutelage of more experienced hands. In this process, what each generation contributes to the next are not rules and representations for the production of appropriate behaviour, but rather the specific circumstances under which successors, growing up in a social world, can develop their own skills and dispositions, and their powers of awareness and response (Ingold, 2001: 141–142).

Now the implications of this view are rather radical. If, as I have suggested, those specific ways of acting, perceiving and knowing that we have been accustomed to call cultural are enfolded, in the course of ontogenetic development, into the constitution of the human organism, then they are equally facts of biology. A skill like playing the cello, being a property of the organism established through practical experience in an environment, is every bit as 'biological' as is walking on two feet. Cultural differences, in short, are not *added on* to a substrate of biological universals; rather they *are* themselves biological. Not long ago, such a conclusion would have been inconceivable. In 1930, no less an authority than Franz Boas, the founding father of American anthropology, had declared that *"any attempt to explain cultural form on a purely biological basis is doomed to failure"* (Boas, 1940: 165). Thenceforth, the absolute independence of cultural variation from biological constraint became a fundamental tenet of disciplinary integrity, one of the few things on which virtually all social and cultural anthropologists were agreed. Indeed it has served us well in our efforts to resist some of the more extreme forms of determinism, for example in debates about the alleged hereditary basis of intelligence, or about the influence of sex on gender. But it is now high time to put this tenet in question. To return to the example of a culturally specific skill like playing the cello: as a property of the organism, the outcome of a process of development, is this not fully admissible as a biological characteristic? Despite Boas' strictures, there is nothing wrong with accounting for this or any other aspect of cultural form on a 'purely biological basis', so long as the biology in question is of development, not genetics.

9. BIOLOGY IS NOT GENETICS

Evidently, the source of the problem is not the conflation of the cultural with the biological, but the reduction of the biological to the genetic. And this reduction, I contend, still lies largely unchallenged at the heart of modern evolutionary theory in its current, Neo-Darwinian incarnation. True, most evolutionary biologists are quick to deny all charges of genetic reductionism. *Of course*, they will say, the human organism, like any other, is the outcome of a developmental process. But in the same breath they will attribute this development to a *complex interaction* of 'biological' and 'cultural' factors, operating in a given environment. And if you ask how biological and cultural factors are distinguished, they will say that the former are genetically transmitted, whereas the latter are transmitted by such non-genetic means as imitation or social learning. Thus despite their initial denials, biology is tied to genes after all, as indeed the logic of Neo-Darwinism requires. The implied essentialisation of biology as a constant of human being, and of culture as its variable and interactive complement, is not just clumsily imprecise. It is the single major stumbling block that up to now has prevented us from moving towards an understanding of our human selves, and of our place in the living world, that does not endlessly recycle the polarities, paradoxes and prejudices of Western thought.

Let me stress that my objections are not to the science of genetics, but to the way in which this science has been commandeered in the interests of an evolutionary psychobiology that is intent on harnessing the gene to an essentialised conception of human nature. Thanks to a huge investment of resources and effort into genetic research, we now know an enormous amount about the genome and how it works. The more we learn about it, however, the less likely it seems that it could do the work that evolutionary theory requires of it. How can a genome that is structurally fluid, given to getting itself tied in knots, susceptible to incorporating bits of DNA from any of the millions of other organisms that inhabit the body at one time or another, and that consists largely of 'junk', possibly provide the foundation for a stable architecture in the form of a more or less immutable set of character specifications?

My contention is that the forms and capacities of all organisms, human beings included, are not prefigured in any kind of specification, genetic or cultural, but are emergent properties of developmental systems. We can understand their stability across generations only by investigating the properties of dynamic self-organisation of such systems. That we know so little about these properties is no reflection of their real importance. It is, however, a reflection of the widespread notion—above all among those with influence or control over the funding of research—that developmental processes are no more than the 'writing out', or realisation, of pre-established genetic potentials. To put it bluntly, the importance we ascribe to genes is a function of the amount we know about them; the amount we know about genes is a function of research funding, and the amount of research funding is a function of the importance ascribed to genes. It is not easy to break out of this vicious circle, especially when the wheels are turning with the momentum, and oiled with the finance, that they are today. Astronomical sums have been spent on the human genome project, to sequence the genes of an idealised human being—a kind of 'universal person' (Brown, 1991)—who never existed in the past and will never exist in the future.

Darwin, as I have already pointed out, categorically rejected the idea that any species, least of all the human, could be characterised by some unchanging essence. But it is precisely the belief in such an essence—a belief that long antedates the rise of modern evolutionary theory—that continues to dominate our ideas of scientific progress. Despite all the hype, the outcomes of the human genome project have not changed in the least the way we think about ourselves; for built into the project is a way of thinking that has already been around for centuries, and which its results merely serve to perpetuate. And the reason for its persistence is simple: it is deeply embedded within the institution of science itself.

10. BACK TO THE FUTURE

I would like to conclude by returning to the theme of human nature. The search for absolute, defining attributes of common humanity does indeed seem a hopeless endeavour, since whatever attribute you choose, there will be bound to some creature born of man and woman in which it is lacking (Hull, 1984: 35). Remember that for modern biology, reconstructed along Darwinian lines, the criterion for species membership is genealogical. Basically, this means that you are a human being if your parents are. If it is human nature to walk on two feet, what of the congenitally crippled? Is he not human? If it is human nature to communicate by means of language, what of the child who is deaf and dumb? Is she not human? If it is human nature to join in forms of social life based on a mutual awareness of self and other, what of those individuals who suffer from autism? Are they not human?

The argument can be turned around the other way as well. Whatever attribute you choose, there is a possibility that some creature of non-human ancestry may turn out to possess it if not now, then at some time in the future. The way a species evolves is not predictable in advance. It is perfectly possible that the descendants of chimpanzees, a million years hence (perhaps once humans have already managed to make themselves extinct), will have developed a fully linguistic capability and be walking on two feet. They have already been shown to be capable of such things up to a point, as well as of other things once thought distinctively human, like making tools. Would they then have become human? In genealogical terms that is an impossibility, yet if it is human nature to walk and talk, then these chimpanzees of the future would have to count as human too.

I have shown that the contemporary appeal to universal human nature, in the name of evolutionary biology, is a defensive reaction to the legacy of racist science left by Darwin's account of the evolution of the moral and intellectual faculties in *The Descent of Man*. But it is an appeal fraught with contradictions. While insisting on the continuity of the evolutionary process, it also reinstates the twin distinctions between biology and culture, and between evolution and history, setting an upper limit to the world of nature that humans alone appear to have breached. More than that, it asserts that human nature is fixed and universal while attributing its evolution to a theory of variation under natural selection that only works because the individuals of a species are endlessly variable. That is why evolutionists find themselves in the curious position of having to admit that whereas in the non-human world, biology is the source of all variability and difference, in the human world it is what makes everyone the same!

Moreover, the racism that modern biology claims to have left behind is never far beneath the surface. The potentially explosive combination of genealogical categorisation and essentialist thinking is still there. Far from dispensing with the concept of race, science has settled on the idea that all extant humans comprise a single race or sub-species, *Homo sapiens sapiens*. According to the currently favoured out-of-Africa hypothesis this race, of so-called 'modern humans', dispersed from its African cradle and eventually colonised the world. It is striking how accurately this hypothesis mirrors the story of global colonial conquest by White Europeans so much favoured by Darwin and his contemporaries. The story may have been turned upside down, but the structure is the same: one dominant race, equipped with superior intelligence, supersedes the rest. And it is scarcely surprising that versions of Afrocentrism, for example, that seek to tell the same story but in a way that emphasises the *differences* between Africans and Whites, tend to assume an explicitly raciological form.

For it is indeed the case that while affirming human unity under the rubric of a single sub-species, we do so in terms that celebrate the historical triumph of Western civilisation. It is not hard to recognise, in the suite of capacities with which all humans are said to be innately endowed, the central values and aspirations of our own society, and of our own time. Thus we are inclined to project an idealised image of our present selves onto our prehistoric forbears, crediting them with the capacities to do everything we can do and have ever done in the past, such that the whole of history appears as a naturally preordained ascent towards the pinnacle of modernity. The bias is all too apparent in comparisons between ourselves and people of other cultures. Thus where *we* can do things that *they* cannot, this is typically attributed to the greater development, in ourselves, of universal human capacities. But where *they* can do things that *we* cannot, this is put down to the particularity of their cultural tradition. This kind or reasoning rests on just the kind of double standards that have long served to reinforce the modern West's sense of its own superiority over 'the rest', and its sense of history as the progressive fulfilment of its own, markedly ethnocentric vision of human potentials.

11. CONCLUSION

I have argued in this article that there is no standard or universal form of the human being, underlying the variations that are so apparent to all of us. In their dispositions and their capacities, and to some extent even in their morphology, the humans of today are different not only from one another, but also from their prehistoric predecessors. This is because these characteristics are not fixed genetically, but emerge within processes of development, and because the circumstances of development today, cumulatively shaped through previous human activity, are very different from those of the past. In this sense the story of human evolution is still going on, even in the course of our everyday lives. But it is not a story of upward movement, along a scale from lower to higher, nor is it one of breakthrough to a superior level of being, over and above the organic. It makes absolutely no sense to claim, as is so often done, that humans have 'transcended biology'. We have not reached above our biology, and we never will. There never was any mighty moment in the past when the upper limits of nature were breached and our ancestors emerged onto the stage of culture, for the very idea of a division between nature and culture is, as I have shown, a Western conceit.

It is, in my view, a great mistake to populate the past with people like ourselves, equipped with all the underlying capacities or potentials to do everything we do today. Indeed the very notion of human origins~~the~~ idea that at some point in evolution these capacities became established, awaiting their historical fulfilment~~is~~ part of an elaborate ideological justification for the present order of things, and as such just one aspect of the intense presentism of modern thought. It is high time we recognised that our humanity, far from having been set for all time as an evolutionary legacy from our hunter-gatherer past, is something that we have continually to work at, and for which we alone must bear the responsibility.

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Cognition, evolution, and sociality

Eugenia Ramirez-Goicoechea

Department of Social Anthropology, Universidad Nacional de Educación a Distancia, UNED, Madrid, Spain
eramirez@fsof.uned.es

Abstract

The aim of this paper is to build up a theoretical framework for a more comprehensive understanding of human cognition as an evolutionary and developmentally complex process constituted through social relations. Sociality and cognition are part and parcel of becoming a human and a person. Thanks to Dynamic Systems Theories, a non-linear, non-dualistic nor deterministic approach is taken for the understanding of the heterochronic mutually specified processes encountered in evolutionary and developmentally systems. In light of neurophysiological evidence, embodiment theory and situated cognition, Neo-Darwinist accounts of cognition are discussed and reviewed. Special attention is given to dialogic relations and socialization in ontogeny, by which knowledge is re-created and embodied in new generations. Last but not least, some considerations are made with respect to the externalization and objectivization of knowledge as recursive mediators/amplifiers for further cognitive evolution that allows, in turn, for more social complexity.

1. INTRODUCTION

Neo-Darwinist theories do not allow for a comprehensive evolutionary theory of cognition. Sociobiology, evolutionary psychology, gene-culture coevolution theories, population genetics or memetics, all of them are limited by their underlying paradigms: (1) cognitivism, as the privilege given to cognition over other mental activity; (2) identification of cognition with information and algorithmic computation; (3) objectivist realism; (4) rationalism and methodological individualism; (5) inability to reconcile sociality and culture with cognition; and (6) stress on genetic inheritance, in detriment of epigenesis, ontogeny, and development.

In this paper, I will try not only to question, some of Neo-Darwinian favourite tenets, but also intend to contribute to the evolutionary epistemology debate regarding the importance of the sociocultural as built and lived in human phylogeny and ontogeny and its environments.

N. Gontier et al. (eds.), Evolutionary Epistemology, Language and Culture, 283–311.

From an epistemological perspective, my work relies heavily on Dynamic Systems Theories: autopoiesis and self-organization theories, complexity, criticality, and chaos theory.[1] These theories favour a non-dualistic and non-deterministic epistemology, paying attention to the emergent properties of systems and the irreversibility of some processes.

I have found these approaches particularly relevant when trying to understand mutually constituted processes as those we encounter when studying evolution and cognition. Many evolutionary (as well as developmental) processes are heterochronically (Gould, 1977) structurally coupled, a history of mutual influences and interactions, in which the-many-to-many relations among them (Shweder and Bourne, 1984) allow for variability in *attractors* (Prigogine, 1980: 29) during it, evolutionary dynamics (i.e. *piggybacking*[2]) .[3] Non-linearity means that cause–effect links cannot be traced nor predicted (Thelen, 1989) because of the dynamicity of the system and the multiple trajectories of its parts among different attractors. Variables may be dependent or independent in respect to scale and level of complexity (Goodwin, 1994). Sensitivity to original conditions (Lorenz, 1972) may be necessary but not sufficient. Many evolutionary and developmental phenomena can be considered as emergencies of self-organized systems that, at some critical point, reorganize themselves towards viability and sustainability (Gánti, 2003) in relation to self-determined selected environments.

My approach is both evolutionary and developmental. As Griffiths (2004) puts it, development affects evolution, while changing over the course of evolutionary forces. In this, I adhere to the Evo-Devo programme for cognitive psychology.

As it will be clear, I claim the importance of sociocultural factors in cognition. Not that the other way round is not true (cf. infra), but *cognitivist* cognitive studies tend to forget the first. I talk about the *sociocultural*, as a

[1] My main references on autopoiesis are Maturana and Varela (1981), Morin (1977), Bateson (1972), and Luhman (1995). For Dynamic Systems theories, I rely on Prigogine (1980), Nicolis and Prigogine (1989), Lewin (1992), Madore and Freedman (1987), Bak (1996), Kauffman (1993, 1995), Gellman (1995), and Cramer (1993). cf. Ramirez-Goicoechea, 2005a.

[2] *Piggybacking* happens when an evolutionary process takes advantage of the force, drive, and speed of another that somehow opens the way for the other to follow or just helps make the way quicker and easier.

[3] Carneiro (1973), when discussing Steward's (1955) and White's (1959) multi-linear approach to cultural evolution, used the metaphor of culture as a bicycle with its set of gears, some short, some long, some quick, some slow. The set moves as a whole but its parts have different rhythms: some processes may speed up others by means of catalysis, or the opposite, slow them down. It is clear that the stratigraphic model of time (the geological level under the biological-organic one, then the psychological, then the sociocultural) does help understanding complexity in hominid evolution (cf. Sinha, 1996; Shore, 1996).

qualifying feature. This is because I do not want to reify culture: what it is important is the dynamics, the relational. There is no way for humans to be social without being cultural and vice versa. I understand this concept as the complex, non-linear process by which human beings create, reorganize, describe, and redescribe, personally and collectively, their conditions of existence (and meaning). This process emerges from the dynamics of an evolutionary history of embodied and relational and engagional capacities brought forth in the life-cycle by a sociocultural environment.

Another milestone in this paper is a non-monadic conception of the individual. The individual does not pre-exist his/her conditions of existence, as a disembodied abstraction. Society is not an aggregate of individuals; it is a globality that emerges from the complex relations and dynamics within its parts.

That is why we support the concept of person as a conscious intentional agent that incorporates a live process in continuous development, in a local and historical context.[4] Human beings as persons can be thought of as co-ontogenetic creatures that organize their lives and are mutually constituted with and by other persons with whom they relate in multiple ways and roles. The individual is already socialized and share membership with categorial and interactional groups, even at the *demographic* level.

2. MODULARITY, DOMAIN SPECIFICITY, AND CROSS-MODALITY

For Neo-Darwinist accounts, i.e. evolutionary psychology (EP), hominid cognition evolved to adapt to the living conditions of Plio-Pleistocene hunter-gatherers (Barkow et al., 1992; Mithen, 1996).[5] These adaptations consisted of genetically incorporated cognitive devices, modules, an unpredicted consequence of Fodor's modularity of peripheral perceptual devices. (cf. Fodor, 1983; also Chomsky, 1957). No general intelligence as in Piaget's psychology.[6] Each module is domain-specific in that its encapsulates a particular domain in the world, in the way of Kantian synthetic a priories, giving structure to the information that comes from different sensory devices by means of specific

[4] Cf. Ingold (1990, 1991), Carrithers et al. (1985), Shweder and Bourne (1984), Toren (1998), Goldschmidt (1993), and Robertson (1996).

[5] How to maintain the continuity of this psychology in sociocultural and ecological contexts as different as in the Neolithic and hierarchical systems is another matter. Cf. Boyd and Richerson (1983) and Boyd (2001).

[6] It is not clear why general capacities should to be less functional than specific ones. Cf. Karmiloff-Smith (1992).

algorithmic computations.[7] These modules evolved in their specificity as fine-tuned capacities for adapting to specific challenges of the environment. Relying on the Western mecano/lego paradigm (Shore, 1996: 116–135), modules are pieces of an articulated structure with no centrality and no neighbouring interdependence of elements: the whole is the sum of its parts.

Evolutionary psychologists believe that all humans share a universal intuitive psychology that would be evoked (Boyer, 1994) under particular conditions.[8] There is not problem accepting that some cognitive abilities may be universal in *homo/femina sapiens sapiens*. But, as for all other *universals*, they can only exist in their local and historical incarnations. Misunderstanding what may be universal with genes, cannot stand up to inspection anymore. Furthermore, diversity and generality can be found at any empirical level: it depends on scale, perspective, and scope.[9]

Nobody denies that, at some level of system complexity, specificity can be acknowledged.[10] But instead of an innate given, specificity can be thought as the result of specialization, the outcome of either punctual or dynamic (cycle) attractors that, for some tasks/experiences, under certain chronotopic conditions, become devices for centrality, coherence, (disordered) order, and directiveness.

Griffiths (2004) distinguishes between different kinds of modules: developmental, functional, and virtual. All of them mean different for evolutionary psychologists and neuropsychologists. Mental modules do not have to correspond necessarily with neurofunctional modules. What may appear as a specific module may be only an aspect of the performance of a functional neural system. Besides, it is possible that different parts of the brain may belong to the same functional module that, notwithstanding, is the outcome of different developmental modules. Modules can be semi-decomposed as subsystems within a hierarchical superior system with which it relates as it

[7] Modules or domain-specific mental capacities have been renamed as *scope-regulated abilities* (cf. Cosmides and Tooby, 2000).

[8] Accepting some kind of universal cognitive devices for particular sets of phenomena is not a problem. This does not entail ignoring the cultural diversity in the boundaries, semantics, practices, and values attributed to these by which they are built up ecologically and cognitively. Cf. Descola and Pálsson (1996) and Hviding (1996).

[9] In cognition, universals have to do also with design and *taskonomy* (Dougherty and Keller, 1982), as the limited possible ways of knowledgeable practice due to evolved/developed/learned capacities, technologies, cultural affordances, and physical constraints. Cf. also Dennett (1998), Bates and Ellman (1993), Quinn (1991). Piaget (1970) used to say that "what is inevitable should not necessarily be innate". Technological convergence in cultural evolution is about this. Taskonomy may have to do also with exaptations.

[10] To give an example, *referential open* words (names, verbs, adjectives) are processed by different neural systems than *closed* ones (connectives, pronouns, determinants, adverbs) (Neville, 1991), independently of further recursiveness and/or co-ontogeny.

does with other subsystems, being that their inner dynamics is the principal motor of development.

Brain dynamics in terms of distribution is very complex. Some cortex areas may be poly-modal, elaborating information from various or different sensory-perceptual devices. Cognitive activity may depend also on multisensoriality as in holistic experiences (as in *flow*, cf. Csikszentmihalyi, 1975) and conflation (Johnson, 1997).[11] In evolution, as in development and in brain reorganization after neurological damage, some parts increase their connectivity for multiple tasks. The superior coliculus and parietal cortex show poly-modality. In congenitally deaf children, parietal and temporal areas normally engaged in speech elaboration and comprehension are *invaded* during development by visual nerves responsive to peripheral vision (Neville, 1991). Blind people, dolphins, and bats process sound and eco-location in the same brain area where seeing people elaborate spatial information, with depths, distances, and shapes, almost like in 3D. Kinesic and haptic experience in blind people—as in Braille reading~~are~~ also mainly processed in the visual cortex area (Maturana and Varela, 1992).

Two processes that are lived experientially together may share some common neural paths. Short-sighted people hear better with their glasses on and people hear better when they can see people's faces (Kuhl and Meltzoff, 1984; Khul, 1985) or their lips moving (not because they know lip reading), in what has been called the *McGurk effect* (McGurk and MacDonald, 1976).

Cross-modality is another kind of mental property. It could be thought in terms of the non-vertical relations between domains in which attractors in one domain capacity become active for another one. Cross-modality has to do with knowledge that is applied from one module to another, because a kind of link has been established between domains, as in metaphor and conceptual blending.

The role of metaphor has always been dear to social anthropologists. Vico already mentioned that our capacity for specialization is limited (Fernandez, 1991) but we have enormous possibilities for combining old things in new contexts. Cross-modality is one of the main sources of creativity and innovation. In fact, cross-modality is at the base of symbolization and implies an increase in the connectivity of neural systems and systems of systems. In evolutionary terms, it may have meant a step further in human *sapientization*.[12] A

[11] Llinás (2001), studying consciousness, speaks of mental states in which waves of the same frequency crisscross many parts of the brain, integrating different neurological structures. The integration of different brain parts through connectivity of neural systems is an outcome of evolutionary process (cf. Ramirez-Goicoechea, 2005b).

[12] Mithen (1996) argues that only when evolved capacities are exaptated for other domains, such as the technical domain, do we see the rapid emergence of our full cognitive abilities.

SLD or sequential learning device (Bruner, 1981) evolved for motor control in bipedalism and manipulation may have been exaptated for communication (Greenfield, 1991; Lieberman, 2002) because of structural design adequacy with the new capacities. Social intelligence (Jolly, 1972; Humphrey, 1976; and Byrne, Whiten, 1988) may have been exaptated for language (Aiello and Dunbar, 1993) in that the neural connectivity it entails may become a condition for language processes. Cross-modality is not automatic and depends also on types and possibilities of experience, including cultural experience. Cultural models may give preference to some metaphors over others in accordance with sensorioperceptual experience, institutionalized meanings (Quinn, 1991; Bruner, 1996) and eco-ideographic relations of societies.[13]

Evolutionary stages may be seen as different moments of functional specialization of some neural structures together with the openness that cross-modality offers for creativity and innovation. Many evolutionary outcomes depend on the local and historical reorganization of capacities, where culture is symbiotically embedded with biology in the direction in which cognitive abilities and action lead. Hence, it seems better to talk of a *soft* mental architecture of the brain where there is specificity within flexibility as well as cross-modality.

3. STRUCTURE IN-THE-MAKING: THE BRAIN AS A SELF-ORGANIZED DYNAMIC SYSTEM

Our brain, and especially our neocortex, is a complex self-organized autopoietic system (Changeux, 1986; Erdi, 1988; Laughlin et al., 1990).

Although neural structures vary in flexibility for re-organization,[14] constraints are not rules and cortical neural reorganization continues in different degrees during lifetime (Dreyfus, 1979; Kostovic, 1990; Edelman, 1992). The phenotype depends on the complex relationship between evolutionary and developmental systems and the local and historical reorganizations of capacities. The difficulty when studying the brain is precisely that its essence relies on its dynamics. We cannot deduce behaviour from the map (Stewart and Cohen, 1997: 151). The brain is the outcome of a phyletic history of a

[13] Totemism and animism may be explained as a specific case of crossmodality in the classificatory system; the first *attracting* social categories under the gravitational force of natural categories, the second being the other way round.

[14] Neural connections cannot be any kind of thing: the design, what neurons are involved, how they fire together, what networks become a network, etc. (Pinker, 2002:83). Cf. Recanzone, 2000, cit. in Pinker, 2002:93; Lawrence and Nohria, 2002.

potential made actual inontogeny. The human brain cortex is the thickest of all animal cortex (Dunbar, 1992). Cortical neurons start to develop from the 10th week of gestation. They are all that there will be around the 18th week. At that point, epigenesis starts. Neurons emigrate to different places following structural and regulatory genes in relation with chemical exchanges of attraction and repulsion with neighbouring cells (Edelman, 1988). Around the third month and once neurons have located, dendrites and axons start to grow and spread in the foetus brain (Scheibel, 1991). Synapto-genesis, neural connectiveness in synapses, already starts before birth, as shown by EEG experiments. Nevertheless, most of synapsis as well as neural death because of inactivity happen after birth (Kellman and Arterberry, 1998: 27). Mental development is cross-cultural in the human species (Rogoff and Morelli, 1989; Konner, 1991). Many of Piaget's developmental stages have correspondence in myelinization and neurological change (Gibson, 1996).

Between 2 and 6 months of age, synapto-genesis multiplies by ten thanks to the profusion of dendrites. At this time, the number of synapses doubles that of an adult. Around 12 months of age, dendrites and connections that have not been stimulated and reinforced start to disappear and there is even neural death (Huttenlocher, 1994). Studies in visual and motor experience confirm this (Wiesel and Hubel, 1963; Kellman and Arterberry, 1998).

The frontal lobe is the area that has grown most in hominid evolution, representing 25% of the human brain instead of the 3% it represents in cats. Frontal and prefrontal cortex and their subcortical and limbic connections are the areas most related to executive, decision, and motivated actions. Its maturation in terms of synapto-genesis, neural death, myelinization and the presence of dopamine is later than other brain areas and coincides with the cognitive and behavioural development of infants between 6 and 12 months. The myelinization of secondary cortical areas is contemporaneous with cross-modal capacities and the elaboration of multi-sensory stimuli and the ability to elaborate more complex totalities. Further myelinization of associative cortical areas, such as in the frontal lobe, corresponds with the ability to manipulate various concepts at the same time and to organize them hierarchically and synthetically. Conceptual blending, integration of space and time, action and consequence, coincide with the neurological development of this area and have been ethnographically proved in different cultural settings (Dasen and Heron, 1981; Werner, 1982). Another big neurological change takes place around the age of 7 (Super, 1991), precisely when most societies start treating the child as a moral agent with responsibility for his/her doings around this age. Neural dynamics continue throughout life, although main structural network building in the brain—connectivity and structuring of cortex—finishes in adolescence when the myelinization of all nerve fibres is completed (Fuster, 1989; Gibson, 1991), and it coincides with sexual maturity.[15]

Modularity and domain specificity theories believe in an inherited functional geography of mental processes. Communication abilities seem to be liberalized in birds and mammals, including primates (Hewes, 1996; Corballis, 2002); the same for facial recognition (Nicholls et al., 1999) even with evolutionary implications (Vallortigara, 1999).

The mind/emotion dualism has relied on a brain geometry as well: left brain hemisphere for cognition and language, right brain side for emotion (Cacioppo and Petty, 1981; Tucker, 1981). It is true that there is some kind of *locality* for the expression and awareness of emotions that may be evolutionarily more ancient than other mental localizations. Nevertheless, left hemispheric specialization for language starts around the first year (Scheibel, 1991); so does emotional cortex structuring in the right hemisphere (Davidson, 1984). Severe impairment may even concentrate mental abilities in only one hemisphere (cf. Battro, 2000).

In fact, both hemispheres are embedded in multiple mental processes (Ross and Mesulam, 1979) showing neurological redundancy at birth. Most abilities are complex enough to be distributed in both sides. Sight alone implies the intervention of more than 30 different brain areas (Kellman and Arterberry, 1998: 205, 209). Brain areas may also be shared at some point for different mental activities (Calvin, 1997). There is evidence of the left hemisphere modulating neurological right side activity as well as organizing some social manifestations of the emotional sphere. Reafferent neurological connections of perceptual areas in the cortex are connected both to the prefrontal evaluative cortex and to the limbic system (Panksepp, 1992; LeDoux, 1998), which is a trait of sapientization (Reyna, 2002). Many cognitive structures in the cortex are triggered by the limbic system, which, in turn, is fundamental for memory, mental processing (cf. Laird et al., 1982) and decision-making (Damasio, 1994).

4. A NEUROSOCIAL MIND

The social and the knowing are part and parcel in human evolution, with different rhythms and mutual attractivity: one can pull the other at one time, in some aspects, the other way around the next time or for other matters. They may also be non-homologically interchangeable in terms of system/environment relations (Ramírez-Goicoechea, 2005a).

[15] Most societies ritualise this stage by means of different forms of symbolic practices that, nevertheless adopt the form of the well-known *rites de passage*.

Concerning evolution, we should pay attention to the social and ecological structures that promote the motivation for employing certain cognitive abilities that may reshape themselves and acquire new potentials in new contexts (Lock and Colombo, 1996). Stages of cognitive evolution in hominids should be envisaged together with the relations that support and instigate them (Lock and Symes, 1996). Most scholars agree that links between the evolution of brain and cognition and social behaviour are tight (Aiello and Dunbar, 1993; Holloway, 1996). Cooperation for migrating out of Africa may have been possible thanks to evolved cognitive and communicational capacities in *Homo erectus* but, obviously, this must have been possible thanks to a certain degree of social complexity, in terms of reciprocal practices, formalized relationships, and social organization.

Nevertheless, I will not address here their evolutionary history during hominization, nor recreate possible scenarios for cognition in respect to grupality and social organization. I will concentrate only on some particular phyletic and ontogenetic issues that apply to the family *homo*, and especially to *homo/femina sapiens sapiens.*

4.1. Encephalization: Becoming Homo

Bipedalism led to the mechanical restructuring of hominid (australopithecus) anatomy. Apart from changes in thigh, torso, and arm muscles, what is especially relevant here is the narrowing of the hominid birth passage due to pelvic restructuring for bipedal locomotion (Domńguez-Rodrigo, 1997; Tatersall, 1999). Birth became more difficult because bigger heads containing bigger brains do not come out that easily.

There is an increase in brain size along hominid evolution from *australopithecines* (400–500 cc), *habilis* (750 cc), *erectus* (1100 cc), *Neanderthal* (1400 cc) and *Sapiens sapiens* (1350 cc) (Holloway, 1996). Encefalization entails not only increase in brain/body size ratio but also differential area growths (especially the prefrontal lobe) as well as increase in potential neural connectivity. Chimpanzees, our closest relatives in terms of extant species similarities share with us 98% of genes. Those that are different correspond mainly to the expression of genes involved in neural connectivity, and inactivation of others implicated in smelling and hearing in favour of vision (Enard et al., 2002; Clark, 2003).

Hominids and especially *homo sapiens* have to be born before the brain is fully grown. A chimpanzee's brain already weighs at birth 45% of the adult one; in humans it is only 25%. In the first year, the human head grows more than 60% of its size at birth. This is only around 30% in one of our closest relatives, the chimp (*pan troglodytes, pan paniscus*) (Passingham, 1982).

The brain finishes growing in size and connectivity thanks to experience during ontogeny, the generative field of biological-organic, psychological, sociocultural, and historical-political relationships of the individual in his/her life-cycle.[16] The capacities of organisms result from the emergent properties of developmental systems (Oyama, 1985, 1992) when engaging in ongoing processes with the environment, a scenario that, for humans, is always social.[17]

4.2. Socialization: Becoming Human

This experience is shaped in a particular/universal sociocultural milieu to which the child is engaged. Human ontogeny can be thought of as socialized biology, captured by a cultural process (Sinha, 1996); it is the *locus* and *tempo* where biology and culture meet each other in the individual (Goody, 1995; Cole, 2002; Greenfield, 2002).In our species, there is not a human nature prior to a sociocultural condition; *sapiens sapiens* is not a given: there is not a *natural* man/woman on top of which culture is placed like a hat. I fully agree with Sinha (1996) in that we should see *homo sapiens sapiens* and humanity as the result of a biosocial process instead of viewing cultural evolution as starting from a terminal point of biological evolution.

Human ontogeny shows some particularities. Animals with high encefalization also have a long childhood and youth, during which synapsis structures through social interaction and play. All primates show an elongated ontogeny (Passingham, 1982), period increased continuously throughout hominid evolution (Foley, 1996). Parental investment in terms of nurture, care, and socialization is also big. This situation corresponds to long-life species, with big brains, few offspring, and little infant mortality.

Humanity is the result of *socialization,* the teaching/observing/learning process to become a proper recognizable member of a social group. Socialization takes place along ontogeny, especially during infancy, childhood, and youth. During ontogeny, everything starts anew: all individuals have a long

[16] Cf. Magnusson and Cairns, 1996; Cairns, and Elder Costello, 1996; Robertson, 1996; Toren, 1990, 1993. In Neo-Darwinian theories, ontogeny has no place. Ontogeny and phylogeny are mutually constituted and specified within the organism itslef (Gould, 1977). Ontogeny provides continuity within the species and discontinuity with respect to the rest. Evolution also depends on ontogenetic processes that are good enough for the viability of the organism, life, and reproduction, as discussed in the *evo-devo* debate (Gerhardt and Kirschiner, 1997).

[17] For humans, all ecological relations should include those perceptions, ideas and values through which they try to make sense of their own actions. Cf. Descola and Palsson, 1996; Roigan, 1988. For the ethnography of *appropriation,* transformation and representation of *nature*, cf. Ellen and Fukui, 1996.

and winding road to go before becoming human. In doing so, they fulfill the capacities of the species.

Premack (1980) talked about an *upgraded* context for primate cognition in the lab context. We can speak of the same for the evolved context of humans: one that includes the knowing and doing of many generations as in extended and externalized knowledge, where the history of the group is re-presented and re-incorporated in artefacts, practices, communicational systems, rituals, and symbols. These become cultural *affordances* (Sinha, 1996; Shore, 1996), objects and ways of learning (Rogoff and Morelli, 1989), procedures (Gentner and Stevens, 1983) and embodied know-how (i.e. Bourdieu's *habitus*), including collective canonical use (normative, evaluative, aesthetic).[18]

What J. Bruner (1983) called the *scaffolded* world we live in, full of reifications and social artefacts, constitutes the scenario for children to build up their own way into a selected environment, the frameworks they will explore for meaning (Bruner, 1996) and (more or less) coherence, in a never-ending process of reworking the legacy of their elders[19] and the choices~~wi~~thin constraints~~of~~ their generation-mates.

Caregivers bring forth and structure children's abilities thanks to: (1) the dialogy of care-giver/child relationships (Schaffer, 1992; Butterworth, 1996);[20] (2) body language, indirect communication (Schieffelin, 1990; Hendry and Watson, 2001), and emotional saliency (Fernald and Mazzie, 1991); (3) infant direct speech (IDS, babytalk, *motherese*) (Fernald et al., 1989; Fernald, 1984),[21] exploratory talk (Mercer, 2000), proper speech styles (Miller and Garvey, 1984), and appropriate commentaries to the situation (Bruner, 1974; 1975); (4) alternate participation as in turn-taking (Mead, 1967; Hobson, 2002); (5) guided, educated attention (Butterworth and Jarret, 1991; Palsson,

[18] Knowledge goes well beyond the limits of our own skin and capacities. Cognition is also social in that it is embodied and stored in artefacts (Donald, 1991), practices and rituals, relationships (Strathern, 1999), procedures, schemas, systems of truth and power (Foucault, 1978). Cognition is socially distributed along other structural alignments.

[19] In social evolution, the extension of the lifespan in hominids contributed to older adults become living devices for the accumulation and teaching of knowledge.

[20] *Dialogy* does not mean total shareability or complete acquiescence, but interpretation, multivoicedness and contrast (Matusov, 1996; Bakhtin, 1990), not to mention a good dose of trust. Neodarwinist anthropological (primatological) *pessimism* even sees cooperation as a selfish behaviour because, as game theorists say, *it pays off to be smart*.

[21] Linguistic and cultural contexts vary (Ochs and Schiefffelin, 1984; Harkness and Super, 1983; Grossmann et al., 1985; Sagi et al., 1985; Pye, 1986). Although Infant Direct Speech is the prevalent case in the majority of cultural settings, children do not need to participate directly as communicating agents with their caregivers to learn how to speek, but only as vicarious ones (Trevarthen, 1988); it is enough that they are present in an interactive linguistic setting that, nevertheless, allow them to be aware of agency, perspective and intentionality in others, with which they may identify through empathy and role assuming.

1994); and (6) anticipatory cognitive and emotional stimulation as in *inter-mental developmental zone* where children learn to become inter-thinkers (Mercer, 2000: 14).

Caregivers socialize providing the focus, the clues, the saliency, the format and dynamic repetitive and standardized structures from which the child will creatively build a shared world of his/her own. The education of attention funds *shared rules* (Mercer, 2000: 40) about ways, contexts, and relevance,[22] of what goes without saying, of what we trust our world to be about and of which we have intuitive, self-evident knowledge.[23] It is by means of guided discovery and observation/imitation (D'Andrade, 1981; Rogoff, 1990) of routines and embodied practices that children are taught dexterities (Palsson, 1994), as shown in workmanship learning (Dougherty and Keller, 1982; Rogoff, 1990; Bloch, 1991). What you learn is to adopt a perspective, where and how to look, listen, etc., how to build up new knowledge, how to creatively rework old pre-existing resources, according to a sociocultural and historical environment. *Symbolic play* is the laboratory where children put in practice and re-work the manipulatory, linguistic, and social skills learnt in infancy (Bruner, 1974; Bretherton, 1984).

N. Chomsky was right: all children learn to speak around the same age. But not because we have genes for speaking (Kupiec and Stojanovik, 2000). Rather, language is the emergence of many micro-dynamics in systems within systems that depend on: (1) evolved/developed specialized/amodal/cross-modal capacities, including neurological and anatomical features; (2) an autopoietic brain open to the world and the experiences it may provide, and (3) a sociocultural landscape that provides a structuring context for our body to develop.

For humans, and somehow for some other primates, we should talk of a *socially engaging/engaged* intelligence.

4.3. Children's Evolved/Developed Capacities

How do children come to be engaged in this social world for them to grow as epistemic agents? Children have sociobiological engaged/engagional capacities.

For a given species, and under similar conditions, the pattern of development is common for all individuals, possibly because of what Super (1981) mentions as *canalization*, the integration of a genetic guidance within an

[22] Something becomes relevant not because it broadens our information about the world as in Sperber and Wilson (1986) but because it appeals and affects us due to what we have become as persons and members of sociocultural groups.

[23] With no declarative memory and conscious trace of its conventional origin.

epigenetic landscape that gives rise to similar outcomes (Johnson and Morton, 1991). Some processes and experiences within suitable conditions have to happen then and there for proper development. If not, permanent negative consequences may come, depending on the threshold passed or the local opportunity (Jacob, 1977) missed. Gottlieb (1971, 1996) speaks of *cognitive windows* for learning, that are active at specific stages of development. We all know the case of singing birds that are not able to contact future partners, therefore, to reproduce, if they have not learned how to sing at the right time in development, becoming *barbari* in their own species.

Human infants come to the world quite well endowed in terms of neural reflexes (Eibl-Eibesfeldt, 1993) and percepto-sensoriality (Kellman and Arterberry, 1998), which explains in part their active, quick, and intense responsiveness to the world and to themselves. Infants are sensitive to some prenatal acoustic clues of prenatal experiences (De Casper and Spence, 1986). But abilities depend on percepto-sensory experience that is culturally embedded and socially triggered. Sensory potential requires interactive learning and fine-tuning during extra-uterine development (Stewart and Cohen, 1997: 140 and ff).[24]

Emotional expressiveness in children appears quite early, thanks to evolved facial muscles (Ekman, 1973, 1979; Izard, 1977). Crying and social smiling are specific human devices for communicating with their conespecifics (Killbride and Killbride, 1975; Eibl-Eibesfeldt, 1983: 41–42) and help establishing the typical human bonding (Bowlby, 1969; Ainsworth, 1983) has important emotional consequences for caregivers' engagement in parenting (Konner, 1991). This tendency and openness towards others is called *intersubjectivity* by Trevarthen (1980, 1988). Babbling is the developmental linguistic (Petitto and Marentette, 1991; Petitto, 2000; Petitto et al., 2000) sequel of this ability to communicate.

Children show early interest in what surrounds them, a landscape mainly composed of faces, voices, and bodily practices. From the age of 2 months, they like faces with all features—nose, eyes, lips, brows—correctly placed (Maurer, 1987).[25] If zebras recognize their mothers by their face stripes, so do human infants by their facial features (Bushnell et al., 1989), preferring them to others (De Casper and Fifer, 1980; Johnson and Morton, 1991). They

[24] Cats cannot distinguish horizontal lines if they have not been exposed to them early in development (Cf. Stewart and Cohen, 1997); rabbits do not distinguish smells if they have not been previously exposed and have some kind of motivation (Freeman, 1991). In a *carpentered* environment, full of angles and straight lines, westerners are much more susceptible of optical illusions than other people in other ethnographic contexts (Super, 1991; Eibl-Eibesfeldt, 1993; Shore, 1996:4).

[25] Maybe due to the human preference for symmetry (cf. Eibel-Eibesfeldt, 1975; Shore, 1996).

also prefer their caregivers' voices to those of others. By 3 months of age they distinguish different voices and even phonemic contrasts in language (Eimas, 1978). At 5 months of age they already recognize individual faces and around 6 months, they perceive gender differences (Kellman and Arterberry, 1998: 274–275). The ability to establish emotional links continues in another *attachment* stage from 6 to 12 months, as shown in the *strange situation* (Ainsworth et al., 1978).

Autistic children have a deficiency in emotional bonding, being later impaired for empathy and social referencing, proto-imperatives and proto-declaratives, recognition of intentionality, perspective-taking and social cognition to various degrees (Baron-Cohen, 1995; Wimpory et al., 2000).

Much has been said about early human *mimetic* capacities.[26] Newborn babies, only 45-minutes old, have been reported to stick their tongues out in imitation of a human face (Hobson, 2002: 30 and ff). It seems there is an ability to connect an event, map it neurologically and offer a motor response to it. Mirror neurons have been found in other primates (Rizolatti et al., 1996; Iacoboni et al., 1999; Nishitani and Hari, 2000) and may constitute precursors for human imitation.[27] When humans imitate, they also attribute intentionality to the interactor,[28] identifying with his/her perspective (Tomasello, 1999) in a continuous interchange of places and roles, proximity and distance (Hobson, 2002: 107); that allow for externalization of self and identification with others. Human imitation is not replication, nor re-production but re-creation: "*[. . .]it is the copying that originates*" (Geertz, 1986: 380).

In conclusion, because of the sensory and mental openness of the child, we can speak of an ecological brain (Bateson, 1972) that is sculpted (Bates, 1979) thanks to socially elicited and upgraded capacities during his/her ontogeny.

5. THE EMBODIED AND EXPERIENTIAL MIND

Neo-Darwinism, in accordance with a rationalist conception of a disembodied epistemic agent cannot provide a comprehensive theory of knowledge and how it is produced.

[26] Cf. Meltzoff and Prinz, 2002; Field, 1985; Heyes, 1993; Nadel and Butterworth, 1999.

[27] Learning how to pronounce is not only done by listening but also by watching how sounds are articulated by lips, tongue, etc. (Skoyles, 1997). Phonetic classification is not based on sounds but on motor ways for producing sounds and consonants. Mirror neurons would easily imitate vowel movements thanks to categoriality and contrastivity, i.e. taskonomy.

[28] Awareness of directionality of gaze as a sign of attention is a phylogenetic trait humans share with other animals such as birds (Griffin, 1992) and mammals, thanks to specialised neuron structures (Perret et al., 1982, 1995; Bailys et al., 1985; Maunsell and Newsome, 1987).

Mind is the emergent outcome of brain neurophysiological activity. Body, emotions, action, and experience are absent in Neodarwinian accounts of cognition. Cartesianism eliminated passion and sensoriality from rationality, because they were thought to belong to the lower instincts and bodily humours (cf. Shilling and Mellor, 1996) that confuse the mind. But mind is not only cognition as in cognitivism. Knowing is also about subjective experience as in desires, motivation, intention, memory, feelings, senses, actions, which are all corporal workings that imply different degrees of neural complexity. We do not decode information and then process it (Searle, 1990). As Lewontin (1982, 1983) suggests, we put much more of ourselves into it. So body, emotions, and practices are relevant for cognition.

5.1. Body

Only through our body can we really produce knowledge, as the intertwining of cognition, memory, and emotion in an ecosocial environment.

Embodiment theories of cognition (Johnson, 1987; Lakoff, 1987; Johnson and Lakoff, 1999; Putnam, 1999) speak of cognitive structures that emerge from recurrent sensory-motor patterns that allow for action to be perceptually guided. Varela and colleagues (1991: 173), say that cognition depends on the kind of experiences that we have thanks to a body with sensory-motor capacities, these capacities being embedded in an encompassing biological, psychological, and cultural context.[29]

5.2. Emotions

Cognition and emotion are mental activities that have been split in Western account of what is the mind, excluding the last one (Ramírez-Goicoechea, 2001). But emotions are important in decision making because they point towards saliency, relevance, value, purposes, communication (Schieffelin, 1983) and directionality for action (D'Andrade, 1995; Williams, 2001). Emotions and feelings tell us about how things go in the world for us and for others (i.e. empathy; cf. Hoffman, 1981). Emotions are like an "information holding system", reverberating loops that keep information active for further mental purposes (D'Andrade, 1981). They allow us to concentrate attention and energy on certain aspects of the situation so we can hierarchically organize and

[29] We do not want to become too *feely/touchy*. Embodied cognition does not preclude inference, abstract or formal thinking, as relatively autonomous and self-organised mental processes subjectivelly devoid of body awareness (cf. Leder, 1990), thanks to recursivity and redescription, reworking and reorganisation in the brain. *Not everything* need to be previously experienced. Inference may well be understood as an emergency of previous experiences mentally reworked and re-elaborated.

reorganize it (Vandamme, 1988). Emotional deprivation and depression have been reported as having consequences in exploratory activity, social intelligence, and inability to envisage mental tasks from a whole perspective. The attribution of emotional and intentional states, as part of a theory of mind and social cognition has been decisive during hominization (Jolly, 1972, 1996; Whiten and Byrne, 1988; Goody, 1995).

5.3. Action and Experience

Humans do not exist detached from their own practices and experience by which they get to appropriate and transform their means and conditions of existence (Marx, 1975), including meaning. It is not a matter of connecting behaviour with its determinants but of social action with its meaning (Geertz, 1983: 34). Lave (1988) has shown that cognition is constituted through practice, embedded in both an interactive situation and a constitutive order (political and ideological domains, collective re-presentations and moral orders). This *macro–micro* environment (Knorr-Cetina, 1981: 2) provides both structure and flexibility for agency to be possible (Giddens, 1979, 1984; Alexander, 1987). The person is best defined as an enacting agent that incorporates a perspective, priorities, beliefs, values, previous experiences, and expectations. Practices have meaning because there is a community of practitioners (Lave, 1988) that share an implicit socially distributed knowledge and collective memory (Connerton, 1989), a series of inter-subjective presuppositions[30] about the intelligibility of actions and actors (Sainsaulieu, 1985: 303; Carrithers, 1992: 87), and hindsight and foresight of the course of action as in a chain of antecedents and consequences (Goody, 1995; Ginsburgh and Harrington, 1996).

Through action, perceptual-cognitive systems select a meaningful environment from which experience is generated for further actions/relations (Gibson, 1979). It is the concept of *perceptual guided action* as developed by Maturana and Varela (1992) from Held and Hein (1958). Perception is not independent of our conceptual schemas (Putnam, 1999: 54; Lakoff, 1987: 261; Johnson, 1987: ix–xxxviii) nor of our experiences. For example, smelling is not a passive mapping of external features but a kind of enactment of that meaning by way of the animal’s embodied history and experience (Skarda and Freeman, 1987; Freeman, 1991). There is no brain activity responding to

[30] Our cognitive capacities, including *social intelligence* owes as much to cooperation, reciprocity, trust, and exchange (Ofek, 2001). Cooperation between primates is based on mutual trust (Bateson, 1988) Cheating and lying entail a displacement between the here and now. But so does trust: if the other does not trust, I cannot lie to him. Cooperative thinking has been fully demonstrated as creatively successful when solving problems or unusual tasks.

smell if the animal (in this case a rabbit) has not been previously exposed several times to the same smell and a motivation (anticipation and expectation) with respect to these experiences has been established thanks to patterns that work as *attractors* for new experiences. This perspective obviously questions the Neo-Darwinian *adaptationist* approach to organisms in general and to humans in particular. The objectivist realism underlying the adaptationist programme holds that the organisms adapt internally to a genetic endowment and externally to the constraints of natural selection, but this is not so. By means of an *operational closure* (as in the cell membrane), they actively *select* an *outer* domain of specification (Varela et al., 1991), an *environment*, through which they build their own inner space. Thanks to this relational closure, a *constituted order*~~le~~ss complex than the environment~~is~~ created for the development and future viability (not optimality) of the system. For any organism, there is an enacted and significant environment, allowed and propitiated by the organism's own affordances (Uexküll, 1940–1982; Gibson, 1979; Ingold, 1989). As in accounts of *niche construction* organisms and environments are mutually especified (Lythgoe, 1979; Lewontin, 1982; Maturana and Varela, 1992; Laland et al., 2000).

Peirce (1987) said that thinking was acting in a chain of thoughts and actions. Ethnomethodology proposed a practical-theoretical agent (Garfinkel, 1984). Ingold (1993: 434) criticizes the underlying dichotomy between the technical-practical and the cognitive shown in most *social intelligence* theories (i.e. Whiten and Byrne, 1988). For the sake of their intrinsic relationships, he distinguishes between thinking as *inward-directed* action, and doing as *outward-directed* action. Thinking, classifying, decision-making, planning and remembering, observing, being, are already actions/experiences, if only because something happens in our brain-in-the-body.[31] Our world is perceived to be enacted and lived from different experiences of engagement[32] and sensory-mental states (Tambiah, 1992; Halton, 1995).

Therefore, it seems better to talk of an *experiential realism* (Lakoff and Johnson, 1999; Putnam, 1999). Things are not more real because they fit more or less in our mental representations but because they are lived through experience. Our qualitative (D'Andrade, 1981; Chalmers, 1997) and *decorated*

[31] Action, meaning, and communication are close by related in child development, showing underlying analogies (not homologies) in categorisation, end-means relations, agent-action-patient links, task constraints and sequentiality (Bates, 1979; Rivière, 1984; Greenfield, 1991).

[32] Action, participation and experience are not reduced to actual agency. For instance, depending on different sociocultural and historical contexts, children are differently immersed in the pragmatic world of their caregivers, in a stage/landscape where, as recipients of other's practices, things happen (and do not happen) *to them*.

version of the world is, somehow virtual, a *figment of reality* (Stewart and Cohen, 1997: 189).

6. RETURN TICKET: THE RECURSIVITY OF COGNITION

In this paper, I have supported a non-deterministic approach to cognition, which, nevertheless, does not preclude for a leading role over other domains at some evolutionary/developmentally point. A property of autopoietic systems as the human brain-in-the-body is, is that of *recursivity*. This means that mental activity may be worked and re-worked itself thanks to connectivity of systems of neural systems towards other grades of complexity, as in Karmiloff-Smith (1992) *re-description*, or Sperber's (2000) *meta-representations*. Autopoietic systems may re-create complexity within themselves by means of subsystems (and their micro-environments) that become relatively autonomous, oscillating in between a dependently independence (Cairns-Smith, 1996: 49) and a liberation from sensitiveness to initial conditions. This allows for these subsystems to become powerful triggering forces on their own for further outcomes and onto other domains.

Motivated knowledgeable human practices become objectified by means of rutinization/ritualization, typification and institutionalization, that introduce new dynamics and emergencies within the system. Through this *externalization*, knowledge becomes objectified, communicable, structured, *knowable* for others to evaluate, discuss, agree upon, and rework. Objectifications could be understood as attractors that orient, direct, and capture human activity in its gravitational space, in its fluxes and exchanges as well as in its more consolidated and structured forms.

The externalized reification processes were started by hominids through their social relationship, embedded in environmental selection/appropriation/transformation (i.e. object production, technology), language, ritual enactments~~inc~~luding body work. Externalization allowed for a new kind of recursivity that may have sped up both cross-modality and especialization as seen in the exponential cognitive and social complexity of *homo sapiens sapiens*.

Devices that were selected, biosocially created, exaptated, thanks to sociobiological cognitive abilities became self-organized and relatively autonomous as new attractors that catalyzed some of these very same capacities, giving them new strength and new direction. Once in motion, as in Tomasello's (1999) *ratchet effect*, or Vico's history in spiral, there is no way back. Language needs some cognitive evolved capacities as its necessary (although not sufficient, cf. Rolfe, 1996) *environment*; but once emerged (Bickerton, 1990) and then fully developed, it may have pulled the cart of cognition further on.[33] Technology may be also the case (Lock and Symes, 1996), as in notation and writing as well (Goody, 1977; Olson, 1980, Olson et al., 1996). As devices to keep track of and record knowledge, things (objects, people, practices, rituals, time, events) became countable and hence controlled in a new way, founding new ways for people to relate to one another and with respect to extensive material objects. Nor less as communicational devices beyond local place and time. This changed social relationships. Social experience became structured and formalized by means of accountability, discourse, classification, and formalized representational systems, proceedings, rules, and meta-rules as well as corporative specialized knowledge and the power it entailed.

7. CONCLUSION

Tim Ingold has asked on different occasions for a new agenda in evolutionary studies that would focus on "the self-organising dynamics and form-generating potentials of relational fields". I think that dynamic systems theories offer a more encompassing approach to the multi-level and multi-modal relationships of embedded processes in human socio-cognitive evolution. If evolutionary epistemology wants to do justice to the complex process of what it is to become a human as a relational organism with in its environment, it is necessary to pay attention to the overwhelming role that the sociocultural has in specifying what and how these relations are. I trust that all of us interested in human evolution and development will benefit from the effort.

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[33] Hence, the Sapir-Whorf debate on the precedence of cognition over language or viceversa, has no theoretical ground. It is a matter of specifying what level of complexity and time we are talking about.

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Cultural evolution, the Baldwin effect, and social norms

Jean Lachapelle

Department of Humanities and Liberal Arts, Champlain Regional College, Université du Québec à Montréal, Québec, Canada
jlachape@globetrotter.net

Luc Faucher and Pierre Poirier

Université du Québec à Montréal, Québec, Canada

Abstract

The goal of this paper is to analyze the role of the Baldwin effect in cultural evolution and to propose that it played a fundamental role in the evolution of social norms. Drawing on a recent interpretation of the Baldwin effect proposed by Godfrey-Smith (2003), it is argued that the Baldwin effect should be construed in terms of *niche construction*. The paper appeals to the works of Deacon (1997, 2003) to illustrate the process of niche construction, and then concludes by applying a Baldwinian process of niche construction to the case of social norms.

1. INTRODUCTION: OUTLINE AND PURPOSE OF THE PAPER

Over the last twenty years, it is fair to say that the Baldwin effect has made a comeback. Indeed, after having been neglected for a long time in the 20th century, more and more evolutionary theorists now seem inclined to go back to Baldwin and the factor he claimed to have discovered in 1896. This trend is evident in a recent book edited by Weber and Depew (2003) entirely devoted to reconsidering the Baldwin effect. The expression the *Baldwin effect* was coined by George Gaylor Simpson in 1953, who, interestingly, was mainly responsible for the bad reputation of the Baldwin effect. Simpson's final assessment of the Baldwin effect was that, while such an effect was theoretically possible, it was most likely a rare instance in nature. For this reason, little attention should be paid to it. Which is exactly what happened for a long period of time in the 20th century; that is, until a renewal of interest for the Baldwin effect could be observed in the works of people who share different theoretical perspectives, such as Dennett (1991, 1995), Pinker (1994), and Deacon (1997).

This new interest in the Baldwin effect was in part sparked by a computer simulation of the Baldwin effect by Hinton and Nowlan (1987), one that was welcomed by John Maynard Smith who saw it as a first step toward

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demonstrating the theoretical soundness of the Baldwin effect. Hinton and Nowlan showed that the Baldwin effect is possible within a strictly Darwinian framework. To do so, they used a genetic algorithm and an extreme simplification of phenotypic plasticity and the genotype. The genotype, which specified the structure of a neural network, was a string of three types of symbols (1, 0, and?). The first symbol (1) specified the presence of a connection, the second (0) its absence, and the third (?) was a switch which could be opened (1) or closed (0) during the phenotype's lifetime (hence it indicated a kind of phenotypic plasticity). Only one genotype had higher fitness than the others, and all of the latter had equal fitness (this is what's called a needle-in-a-haystack function). The simulations showed that evolution unaided by plasticity is very slow (since it literally had to find a needle in a haystack). But allowing phenotypic plasticity made search in genetic space faster. Modification of the plastic phenotypes consisted in randomly drawing a value for each switch present in the genotype, until either the solution was found or the organism died. The genotypes that were initially close to the optimal genotype thus had a chance to be preferentially selected for reproduction (with mutations) and came to dominate the population. Once the whole population was closer to the optimal genotype (i.e., close to the needle), those genotypes that, by chance (mutation), had their switch (the? symbol) replaced by the appropriate value 0 or 1, according to the optimal genotype, were then preferentially selected over the others since they were then more likely to reach the solution before dying. Thus, one finds a simulation of the phenomenon described by Baldwin: plastic phenotypes that are first favored by selection but then replaced by fitter non-plastic genotypes; hence, phenotypic plasticity followed by genetic assimilation. It should be noted that the last switches take a very long time to be replaced since little selective pressure is exerted on them (they are almost sure to find the solution by trial and error before they die).[1]

In this paper we will first start with some introductory remarks on the Baldwin effect, our goal being to put the issue into perspective. Then a distinction between two versions of the Baldwin effect will be proposed, which will be referred to as the *narrow* version and the *extended* version of the Baldwin effect. Our claim will be that the extended version of the Baldwin effect is to be preferred to the narrow version. We will then appeal to the works of Deacon (1997, 2003) on the evolution of language to illustrate what the extended version of the Baldwin effect entails. Finally, we will make use of this extended version of the Baldwin effect to argue that it played a fundamental role in the evolution of social norms.

Our endeavor is congruent with one of the two main branches of evolutionary epistemology proposed by Bradie (1986, 1994), namely the distinction

[1] We thank Jean-Frédéric De Pasquale for his contribution here.

between the evolution of epistemological mechanisms programme (EEM) and the evolution of epistemological theories programme (EET; see the introduction by Gontier in this volume). While the latter seeks to construe the evolution of ideas and theories by analogy with evolutionary models, the former attempts to identify the evolution of mechanisms (e.g., the brain) that are responsible for the production of knowledge and cognition broadly conceived. What we attempt to do in this paper comes within the framework of the EEM. Specifically, we contend that the Baldwin effect, properly understood, is a mechanism whose role in the evolution of some social behaviors (Godfrey-Smith, 2003) has been underestimated.

2. WHAT IS THE BALDWIN EFFECT?

All of this raises some important questions. What is the Baldwin effect? What is this effect supposed to do? What is its explanatory role in the theory of evolution? Is there any empirical support for it?

Two remarks are in order before we even attempt to answer these questions. First, as Depew (2003: 6) rightly points out in a recent paper, the Baldwin effect is neither a theory-neutral empirical phenomenon, nor a mechanism clearly identifiable by all evolutionary theorists. Rather, it is a hypothesis whose acceptance depends to a great extent on one's theoretical background, for instance one's approach to evolutionary theory. Second, our aim here is *not* to carry out a thorough exegesis of Baldwin's works. Even if we aimed to do this, it is doubtful whether we would ever pinpoint with precision what Baldwin had in mind with his *new factor in evolution*, because Baldwin himself changed his views from one paper to the other (Griffiths, 2003). Rather, our goal is to find what is of theoretical interest in the Baldwin effect in light of recent developments in evolutionary theory. Thus, the interpretation of the Baldwin effect we propose below (see Section 3) is informed by our commitment to a certain version of evolutionary theory. More specifically, our view of the Baldwin effect is influenced by the works of Boyd and Richerson (1985, 1992, 2002) on the evolution of culture, as well as by recent works in evolutionary theory that go under the name of Developmental Systems Theory (DST for short; see most contributions in Oyama et al., 2001).

In its most general sense, the basic idea underlying the Baldwin effect is that learning can, under certain conditions, affect the direction and rate of evolution by natural selection (Depew, 2003: 3). At times, when they felt particularly confident (and temerarious), Baldwin and Conwy Lloyd Morgan went so far as to claim that learning is *the* leading mechanism driving evolution, which they opposed to natural selection. Such a stance might partly explain why most of the key players of the Modern Synthesis (see, e.g., Mayr, 1963) had little sympathy for Baldwin. However, as exaggerated as this claim may be, it must be understood in its proper historical context. Indeed, it was put forth at a time when Weismann had just given the final blow to Lamarckism, and some theorists like Baldwin and Conwy Lloyd Morgan felt that an evolutionary theory without some Lamarckian insights would be incomplete. Hence, they stressed the importance of learning in the evolutionary process.

Yet to claim that learning can affect evolution is so general that it only begs the question, not to mention that it can be seen as trivial. Which is why the Baldwin effect is typically broken down into two components, namely: (1) learning and phenotypic plasticity; and (2) the genetic assimilation of the trait learned. This second component was included in the Baldwin effect thanks to an interpretation proposed by Waddington in 1953 after having conducted experiments with fruit flies, in which he showed that some aspects of their phenotypes can become part of their genotypes in later generations. Here is how these two elements work according to this general description of the Baldwin effect from Godfrey-Smith (2003: 54):

> Suppose a population encounters a new environmental condition, in which its old behavioral strategies are inappropriate. If some members of the population are plastic with respect to their behavioral program, and can acquire in the course of their lifetime new behavioral skills that fit their new surroundings, these plastic individuals will survive and reproduce at the expense of less flexible individuals. The population will then have the chance to reproduce mutations that cause organisms to exhibit the new optimal behavioral profile without the need for learning. Selection will favor these mutants, and in time the behaviors which once had to be learned will be innate.

It is worth highlighting the main elements of the Baldwin effect in this description. The first point is that a particular environmental condition must prevail in order for the Baldwin effect to be triggered. We will argue below that such a condition~~in~~ which some evolutionary problems arise that call for a solution in terms of engineering[2] ~~is~~ crucial. Note also the role of learning and plasticity here. The individuals with the ability to learn and modify their behavior given this new environmental condition have an edge over those lacking this ability and plasticity. And because of this edge, they are more adapted to their environment and this is likely to increase their fitness. In the

[2] In what follows, whenever we are referring to an organism's ability to *engineer* its environment, we are not assuming that such an organism has intentions with specific goals in mind (though this might be possible in the case of certain species). By engineering, we simply mean an organism's ability to modify or construct its environment in a way that is likely to be conducive to its fitness. So, for instance, an earthworm changing the structure and chemistry of the soil in which it lives engineers its environment in the way just defined (Odling-Smee, Laland, and Feldman 2003: 11).

long run, mutations favoring this learned trait are selected by natural selection. As a result, the trait becomes encoded in the genome and the individuals with this innate trait avoid the cost of learning it, which is the main evolutionary pay-off of the Baldwin effect on this account.

Let us mention very briefly two examples of phenomena that are often cited in the literature as supporting the Baldwin effect. First consider the case of lactose tolerance. A long time ago, adults could not digest milk because of the lactose contained in it, which requires the production of a specific enzyme in sufficient number. This changed completely in populations of herders of milk-producing animals. As time went by, the specific alleles responsible for the production of this enzyme did not get shot down after weaning anymore, thus leading to lactose tolerance. Second, consider the case of (partial) resistance to malaria. Populations that began practicing agriculture and cutting down trees became increasingly exposed to malaria thanks to a greater presence of mosquitoes. As time went by, a specific gene coding for resistance to malaria evolved and protected *some* individuals against this disease; indeed, when produced in two copies this specific gene triggers a specific form of anemia.

These two examples are cited by Deacon in *The symbolic species* (1997) as good candidates for the Baldwin effect. Interestingly, in a recent paper Deacon (2003) has changed his perspective and his remarks will prove to be useful for what follows. Indeed, Deacon remarks that *if* the Baldwin effect is *narrowly* conceived as implying a process going from a learned trait to the genetic assimilation of this trait, it is far from clear that these two examples provide any support for such a process. On the one hand, there does not seem to be a great deal of learning underlying the change in behavior in either of these two cases. On the other hand, genetic assimilation does not seem to take place~~no~~ phenotypic trait becomes part of the genotype. “ *Nothing is made more innate,*” as Deacon (2003: 92) puts it.

3. TWO VERSIONS OF THE BALDWIN EFFECT

So, what does this tell us about the Baldwin effect? This certainly seems to provide support for the idea that there exists no theory-neutral phenomenon of the Baldwin effect. In fact, for theorists suspicious of the Baldwin effect, the two examples just discussed reinforce their conviction that it can be neglected and that the phenomena it purports to explain can be accounted for using a standard version of evolutionary theory.

We believe that such a conclusion is premature and rests on a conception of the Baldwin effect that is too stringent.[3] Therefore, we would

[3] It seems to us that Downes (2003) commits just that kind of mistake. He defines the Baldwin effect in a very narrow way, argues that there are no documented and uncontroversial cases

like to make a distinction between two different versions of the Baldwin effect:

> The *narrow* version of the Baldwin effect (what could be called the Baldwin-Waddington effect): here, the Baldwin effect assumes that the learned trait eventually becomes part of the genome.
>
> The *extended* version of the Baldwin effect (what could be called the Baldwin-Deacon effect): here, the Baldwin effect must be construed in terms of *niche construction*.

Let us begin with some remarks on the narrow version. This is essentially the traditional view of the Baldwin effect. We see two major problems with it. The first is the one pointed out by Simpson in 1953, namely that such an effect, while theoretically plausible, is bound to be rare in nature. If that is the case, then we also see no cogent reason to make such a big fuss about the Baldwin effect. But our second issue with the narrow version is even more substantial. It has to do with what can be called the *modularity* assumption of this version; that is, the idea that a trait which used to be learned can become innate in such a way that there is a given set of genes (or an *organ* or a *module*, depending on one's terminology) that code *specifically* for this trait. Such an assumption rests on a dichotomous view of biology according to which one can easily distinguish between what's learned and what's innate. Given our sympathy for DST (Oyama, Griffiths, and Gray, 2001), which stresses, among other things, the importance of all the causal resources contributing to the ontogeny of phenotypes, we claim that this assumption is highly questionable. It seems to us to be an extremely difficult task to partition the causes of phenotypes into clear-cut categories (i.e., *learned* versus *innate*) the way this version assumes it can be done. In fact, from a DST perspective the case can even be made that no trait is ever entirely innate, for no trait can unfold without the input of many environmental resources (Griffiths and Gray, 1994). For instance, Nijhout (2001) shows that even with something as simple as sickle-cell anemia, there is *no such thing as a one-to-one correspondence between genes and phenotypes*; this trait seems to be so sensitive to the developmental context in which it unfolds that any minor change in one of the ontogenetic parameters can completely modify how (or even whether) the trait develops. Schaffner (1998) demonstrates the same thing with regard to the behavior of the nematode *C. elegans* and suggests that, if there is no simple genotype-phenotype relationship for the behavior of simple organisms,

of the Baldwin effect, and then concludes it is not justified to extend evolutionary theory so as to include the Baldwin effect as one of its mechanisms. In our view, this comes close to being a straw man fallacy.

the same is very likely to be true for the behavior of more complex organisms like us.

But the narrow version need not be the only way of understanding the Baldwin effect. Another way to view it, is as outlined in the extended version above. We owe this construal of the Baldwin effect in terms of *niche interpretation* to an illuminating paper by Godfrey-Smith (2003), who credits Deacon (1997) for having been the first to view the Baldwin effect in such a way. Interestingly, Deacon (2003) seems to agree with Godfrey-Smith's interpretation. Moreover, other theorists (Griffiths, 2003) argue that the extended version is more in line with what Baldwin had in mind than the Baldwin effect as narrowly conceived. Before explaining what it means to understand the Baldwin effect in terms of niche construction, it is worth pointing out that the extended version of the Baldwin effect *encompasses* the narrow version but does not necessarily *imply* it. Thus, some of the examples of the Baldwin effect that did not fit with the narrow version might be incorporated into the extended version.

3.1. Two Definitions of Niche Construction

Our contention that the Baldwin effect should be understood in terms of niche construction can be convincing only insofar as we clearly define what is meant by niche construction. Thus, we propose two definitions of niche construction, both of which draw heavily from a recent book by Odling-Smee et al. (2003). Here is a first general definition of the Baldwin effect:

> *The general definition of niche construction*: The process whereby organisms modify their environment, which may result in a change in the selective pressures of such organisms, which in turn may affect how natural selection operates in this population.

The classic example illustrating this first definition of niche construction is that of beavers building dams. Odling-Smee et al. (2003) make it clear that this kind of niche construction has an impact on at least three different levels. First, it affects the other beavers in this specific environment. But it can also have an impact on some of the other species in that environment. Indeed, one can imagine a species of fish having to get around a dam to reach its source of nutrition. Finally and most importantly, niche construction thus understood is likely to affect not only the offspring and descendants of beavers, but also the offspring and descendants of some of the other species in that environment. Odling-Smee et al. (2003) refer to this last process as ecological inheritance. They claim that, under certain circumstances, niche construction in general and ecological inheritance in particular may involve changes in the environment that are so important and profound that they literally modify the selective pressures that will prevail for these species in their future environment. Moreover, such processes, which were neglected for too long in evolutionary theory (Lewontin, 1983), are likely to have deep evolutionary consequences; they may completely modify or redirect the evolutionary trajectories of certain species. In this sense, niche construction is more than the mere work of natural selection; it is more than a mere *extended phenotype*, as Dawkins (1982) would say. It is a process with a causal efficacy of its own and one co-contributing, with natural selection, to the evolutionary process.

What is even more interesting for our purposes is that niche construction has a dynamic of its own in organisms possessing culture. And we happen to believe, like Godfrey-Smith (2003: 65), that the Baldwin effect is likely to be particularly useful in explaining social behaviors. So here is a second, more specific definition:

> *The Baldwin effect defined as cultural niche construction*: A process whereby organisms possessing culture modify their social and cultural environment; in doing so, they may change the selective pressures of their environment, which may result either in:
>
> (1) a change in the cultural traits and behaviors of the individuals of this population
> or
> (2) a change at the anatomical, neurological, or genetic level in the individuals of this population
> or
> (3) both (1) and (2) – not necessarily at the same time, though.

The Baldwin effect understood as a cultural niche construction seems to us to be of the utmost importance. It is a way for cultural organisms to cope with evolutionary problems prevailing in their environment by modifying and re-engineering their social and cultural ecology. When this happens, certain cultural traits and behaviors may become part of the *developmental matrix* (Sterelny, 2003: 172) of the members of this population, a matrix which is transmitted from one generation to the next; that is, such traits and behaviors form the background against which the ontogeny of these organisms takes place, just as dams are part of the environment of beavers. This process is made possible and enhanced thanks to cultural transmission (Boyd and Richerson, 1985). In the following section, we appeal to Deacon's account of the evolution of language to illustrate how a Baldwinian process of cultural niche construction operates. Then, in Section 5 we attempt to demonstrate that the evolution of social norms can be understood along the same lines.

In what sense can all of this still be seen as the Baldwin effect? In other words, what's our rationale for extending the Baldwin effect in such a way?

First of all, the extended version still captures the essence of the Baldwin effect as narrowly construed but without its pitfalls. On the one hand, plasticity and learning are still likely to play a fundamental role in the process of modifying and re-engineering a population's environment, whether it be social, cultural or physical. On the other hand, some elements of this engineering process are transmitted and become part of the developmental matrix of organisms, but we don't have to assume that they are coded in the genome. In fact, from a DST perspective it is of secondary importance to try to find out whether the elements are *assimilated* at the genetic, neuroanatomic, or cultural levels, for all these levels are causally interdependent.[4] As long as the cultural traits and behaviors are reliably re-constructed and transmitted from one generation to the next, then it suffices to say that these "[. . .] *facultatively acquired behaviors become entrenched in the social life of the population*." (Godfrey-Smith, 2003: 63). Which points to our second justification for the extended version of the Baldwin effect, namely that it applies to a much larger class of phenomena than the narrow version, which is too restrictive. For this reason, its explanatory scope is enhanced. For instance, it seems to us that the two examples mentioned before (lactose tolerance and resistance to malaria) can now be accounted for using the extended version of the Baldwin effect. Moreover, we argue below that the extended version is particularly useful to explain the evolution of language and social norms.[5] Our final reason for extending the Baldwin effect in such a way is that this new version is consistent with recent works in evolutionary theory. For instance, it fits with many of the claims made by DST advocates, who stress the role of epigenetic inheritance (e.g., ecological inheritance) and call our attention to processes and phenomena that have been neglected in a gene-oriented theory of evolution.[6] It is also in line with a multilevel view of selection (Sober and Wilson, 1998; Deacon, 2003) according to which natural selection does not merely occur at the genetic level but can also occur at many levels of the biological hierarchy.[7]

[4] Of course, for certain analytical purposes it can be very important and useful to stress the separate contribution of different causes. For instance, in the case of the evolution language à la Deacon (1997, 2003), it is worth pointing out that changes in the cultural environment (situation 1 above) led to changes at the neuro-anatomic level (situation 2 above; thus also situation 3). In the case of the evolution of social norms, we are rather skeptical that major changes took place at the genetic or neuro-anatomic levels as a result of changes in the cultural environment. But we wish to remain agnostic on this issue here.

[5] We conjecture that it might be useful to explain many other phenomena, though no attempt to back up this claim will be made here.

[6] In fact, we know of at least one DST theorist (Griffiths 2003) who seems to argue that Baldwin himself was more interested in epigenetic inheritance than genetic assimilation *per se*.

[7] Obviously, we are more interested in the process underlying the extended version than in the name 'Baldwin' itself. Therefore, if one is unable to overcome one's impression

4. CULTURAL NICHE CONSTRUCTION AND THE EVOLUTION OF LANGUAGE: DEACON'S ACCOUNT

It is now time to turn to Deacon's (1997, 2003) works on the evolution of language, our goal being to illustrate how cultural niche construction operates before we focus on our main example in the following section. Our analysis of Deacon's account is admittedly quite superficial and incomplete. Doing justice to all its details and complexity is beyond the scope of this paper. In any case, the details are not crucial here as we are more interested in the *type* of explanation put forward by Deacon, which Deacon himself views as an example of niche construction in a recent article (Deacon, 2003).[8] For the sake of analysis, we divide the story told by Deacon into three main phases; we do the same thing with the evolution of social norms in the next section. As anyone acquainted with the works of Deacons knows, his account eschews any simplistic cause and effect analysis. Clearly, the three phases are intertwined and interdependent.

4.1. Phase 1: Some of the Evolutionary Problems that Triggered the Evolution of Language

For Deacon, the evolutionary problems that pre-existed any forms of symbolic communication and that eventually paved the way for the evolution of such forms are essentially social problems. More specifically, they were problems having to do with the social organization of the group. Given our aim and the limits of this paper, we can only mention the main ones very briefly. Groups got bigger and bigger, which called for more coordination between the members of such groups. There was also a need for a better division of labor not only between men and men (e.g., for hunting), but between men and women; for instance, men became more and more invested in the education of their offspring, but because they had to hunt in big groups the issue of sexual exclusivity arose; how, indeed, could men ever be sure that their women were not sexually promiscuous when they were away. Finally, in such a harsh and changing environment (see Section 5.2. below), there was an increased pressure to find a way for parents to transmit crucial

that the Baldwin effect necessarily implies a process of genetic assimilation as described in the narrow version, then one should just set Baldwin aside and call the process niche construction. Or, alternatively, one could refer to what we are proposing as as a move 'beyond the Baldwin effect.'

[8] What is more, one may not be in total agreement with some of the details of Deacon's account while still thinking that the type of explanation put forth is the right one. For instance, one may not share Deacon's view on the importance of marriage in the evolution of symbolic communication.

information to their offspring, information that would be conducive to their fitness.

4.2. Phase 2: A Baldwinian Process of Cultural Niche Construction

The existence of all these evolutionary problems (and more) created the conditions for a new social and cultural niche to arise with its own selective pressures. This is the most fascinating aspect of Deacon's thought. The first forms of symbolic communication emerged as a solution to problems that are social in nature. On this view, the emergence of symbolic communication must be thought of as a solution to a problem of social engineering. More precisely, the evolution of symbolic communication is the outcome of important social changes and arrangements whose goal was to ensure more cooperation between the members of the group, stabilize the relationships between men and women, and favor social transmission and social cohesion. In other words, the rise of symbolic communication was made possible thanks to changes made to the social environment. But that is not the end of the story for Deacon. Once these changes were made and once the first forms of symbolic communication emerged, linguistic evolution itself (Deacon, 2003) became a cultural niche exerting its own selective pressure and triggering profound changes at many levels. Symbolic communication was the new cultural niche of hominids for Deacon (2003: 93) "*The social evolution and transmission of symbolic communication […] created a radically different niche than that experienced by our non-symbolic ancestors, the Australopithecines and other apes*." Which led to the third phase.

4.3. Phase 3: Changes at the Cognitive and Neuro-Anatomic Levels, and Universality of Language

In fact, linguistic evolution was so powerful on Deacon's account that it brought about the main physical changes necessary for language to become a universal phenomenon. Among other things, this included a greater ability to memorize; an expansion of the frontal lobe; an ability to analyze phonemes; a new position of the larynx; a greater ability to imitate the voice of others; and so on (Deacon, 1997). Reflecting on his approach to the evolution of language developed in *The symbolic species*, Deacon (2003: 94) says:

> So, in a way not radically dissimilar to the way the construction of beaver dams led to an evolutionary change in beaver anatomy and physiology, making them more aquatic, the human-created niche we call culture had its primary influence on neurologically based systems. I have argued that the major neuroanatomic differences that distinguish humans from other

apes, other primates, and from mammals in general, are the anatomical effects produced by this radical niche construction.

What are the key points to glean from Deacon's story? As far as the *type* of explanation proposed is concerned, the story fits nicely with an explanation in terms of cultural niche construction as described above.[9] Thanks to modifications made to the social and cultural environments of hominids, new selective pressures were created which in turn led to physical changes in hominids. Furthermore, the story offered here still captures the essence of the more traditional version of the Baldwin effect. While plasticity and learning understood in terms of social and cultural engineering obviously play a role in such a scenario, there is no denying that language has become part of the developmental matrix of human beings.[10] However, for Deacon this need not have involved a process of genetic assimilation—there is no organ or module for language per se. In addition to learning, the selective pressures of linguistic and cultural evolution are *still* as causally important in the ontogeny of language as are the more "biological" constraints.

5. THE EVOLUTION OF SOCIAL NORMS AND CULTURAL NICHE CONSTRUCTION

We now want to apply the same type of explanation to the evolution of social norms. Social norms are essentially rules stating how one should behave in a given cultural group. There are two sides to the coin with social norms, namely, they forbid certain types of behavior but they also encourage other types of behavior (Boehm, 1999; Nichols, 2002). The universality of social norms constitutes a puzzle. Why is it the case that such rules prevail in all cultural groups? Moreover, how is it possible that these norms often overlap from one group to the other? That is, most groups typically forbid the same kind of behavior (i.e., rape, murder, incest, theft, lies, etc.) while also favoring

[9] Deacon's story raises the question of the relationship between the social and the cultural. Roughly, here is our perspective on this issue. The social preceded culture and was necessary for it to evolve. In this sense, no culture without a social life. However, the reverse is not true. Many species no doubt have a social life (e.g., insects) but lack culture. Having said this, none of this implies that in species in which culture emerged, culture became prior to the social. Culture is just an additional process (i.e., an additional layer of causation) on top of the social, one which, under certain circumstances, can work in conjunction with the social to bring about evolutionary phenomena that can hardly exist in species lacking culture (e.g., symbolic language, social norms).

[10] Interestingly, Pinker (1994) also relies on the Baldwin effect in his analysis of the evolution of language. However, in his case a standard and narrow version of the Baldwin effect seems at work, in that a process of genetic assimilation occurs which results in a *language instinct*. Needless to say, Deacon rejects such a view.

the same kind of behavior (i.e., generosity, cooperation, a division of labor, etc.).

There are at least three possible ways of explaining this puzzle. First, there is the biological (or sociobiological) hypothesis: social norms are innate. The problem with this hypothesis is that there seems to be little empirical evidence to support it. Moreover, we are rather skeptical vis-à-vis the possibility of specific modules *encapsulating* specific behaviors and psychological dispositions (see Poirier et al., manuscript). At the other extreme of the continuum would be the environmentalist hypothesis: social norms have emerged in function of the demands of the local environment. The problem with this hypothesis lies in the relative homogeneity of social norms, given the fact that the environments of hominids seems to have been *heterogeneous* over time and space (Potts, 1996; Boehm, 1999; Sterelny, 2003); what, then, could explain this convergence of social norms? A third and, we believe, more plausible explanation is the cultural niche construction hypothesis: social norms have evolved in hominids as a result of major modifications to the social and cultural environment, modifications which have been transmitted, reinforced and accelerated by a process of cultural evolution (Boyd and Richerson, 2002).

5.1. The Three Phases in the Evolution of Social Norms

Here again we divide the evolution of social norms into three phases. It is worth pointing out that this is done for analytical purposes and that we are aware that such a process occurred over a period of at least two million years in the hominid lineage. As is the case with all the explanations of the evolution of human cognition, the scenario offered here is bound to be fairly speculative (Sterelny, 2003). We contend that such scenarios should be assessed in terms of degrees of plausibility given the evidence available. Moreover, while one may want to take issue with some of the specific points mentioned in this story, one may nevertheless agree with the type of explanation proposed in terms of cultural niche construction.

5.2. Phase 1: Some of the Evolutionary Problems that Triggered the Evolution of Social Norms

We identify two general sets of problems in this phase. Clearly, these two sets of problems are intertwined and interdependent so that no simple cause and effect analysis can do the job here. A first set of problems can be referred to as *environmental* problems. As is now well documented (Potts, 1996, Richerson and Boyd, 2000), our ancestors had to live in an environment in which dramatic climatic changes occurred at a fast pace. In a recent book, Sterelny (2003: 128) refers to this problem as the "[…] *ecological trigger of hominid evolution* […]," which he describes as follows:

> Hominid evolution took place in a world that was becoming increasingly inhospitable to ape-like ways of life. Hominids evolved in a habitat of increased seasonality and aridity, changes involving the transition from forest to savannah and open woodland. These changes reduced resources that were at the core of ape life, in particular the ripe fruit on which chimp diets are based.

This summarizes in a concise way the major environmental problems that arose in the hominid lineage. The rapid and important climatic changes forced hominids out of the forest. That resulted in a change of habitat which called for a new diet. While in the forest hominids mainly ate fruits, but now out in the open in the savannah they had to adopt a meat-oriented diet. Obviously, obtaining the necessary meat required hunting animals, but that exposed our ancestors to predators (Sterelny, 2003). All of these environmental problems thus raised some *social* problems, which is the second set of problems in phase 1. Indeed, hunting and a greater exposure to predators had at least two major consequences. On the one hand, they called for bigger groups as security lies in number, a predator being less inclined to attack a group of thirty people (Dunbar, 1999) than a couple of individuals. On the other hand, they also required hunting and defense strategies~~in~~ other words, more coordination and cooperation were necessary in groups getting bigger and bigger.

These are the environmental and social conditions that triggered two additional social problems in phase 1 which are key to understanding the evolution of social norms. The first one is known as the *freerider problem* (Dunbar, 1999). Freeriders are essentially individuals that want to benefit from the advantages of social life without incurring the costs associated with it; for instance, an individual might want to eat the meat collected by other members of the group, while not being willing to share after catching a prey himself (e.g., he will hide to eat the meat). In a big group, it is harder to monitor the behavior of all individuals, so freeriders can more or less go around without getting caught. If many individuals reason along the same lines, then this might undermine the very possibility of cooperation that is so crucial for a group living in a harsh environment. In short, freeriders are potentially quite disruptive for the group and likely to be the source of conflicts. Exactly the same can be said about the second problem, which has to do with *individuals with alpha-type behaviors*. A natural disposition to seek power and dominance has been observed in humans, just as it has been observed in other primates (de Waal, 1989, Boehm, 1999, 2000). What this means is that human nature is such that, if given the opportunity, most individuals seem inclined to use power to dominate other individuals. In concrete terms, this may give rise to situations in which one (or a couple of) individual(s) has (have) access to all the females; gets more food (or better quality food) than the other members of the group; makes self-serving decisions for the group at the expense of the other members of the groups; etc. (Boehm, 1999, 2000). If that is that case—that is, if we assume that there is such a natural disposition and that all the other problems mentioned also prevail~~the~~n such alpha-type behaviors are bound to be disruptive for the group and the source of great tensions that are likely to undermine any attempt at cooperation; specifically, such behaviors favor *within*-group selection (i.e., more *competition* within the group; Sober and Wilson, 1998; Boehm, 1999) at the expense of cooperation. Yet cooperation is exactly what was needed to make it in that kind of environment.

5.3. Phase 2: A Baldwinian Process of Cultural Niche Construction

How, then, are we to suppose that people came out of a situation that can only be described as a vicious circle? Here again we want to suggest that the evolutionary problems of phase 1 called for a solution that is best thought of in terms of *social engineering*. Specifically, it is hypothesized that hominids made some substantial modifications to their social and cultural ecology that allowed them to cope with these evolutionary problems. Anthropologist Christopher Boehm (1999, 2000) whose works inform much of what follows in phase 2, refers to this process as the rise of *egalitarianism*, which resulted in the following changes:

a) The emergence of leveling mechanisms limiting the power of individuals with alpha-type behaviors. Based on his rich and comprehensive survey of the ethnographic literature, Boehm (1999, 2000) concludes that all cultural groups (either nomadic or foraging) have come up with rules and strategies designed to constrain the freedom and power of individuals with alpha-type behaviors. Such leveling mechanisms, as Boehm calls them, are there to ensure that no individual gets to have his cake and eat it at the same time; for instance, rules concerning the sharing of meat and sexual exclusivity (e.g., marriage rules) are clearly established in several groups. Boehm suggests that cultural groups dealt with the problem of alpha-type behaviors by developing a group aversion to within-group conflict and to dominance; in short, they modified their social ecology. In a series of fascinating papers, Paul Bingham (1999, 2000) goes one step further by arguing that weapons also played a fundamental role in limiting the power of individuals with alpha-type dispositions. While originally conceived to hunt, weapons were soon used as a threat by the group to prevent these alpha-type individuals from gaining too much power.

b) The implementation of punishment mechanisms for freeriders and individuals with alpha-type behaviors. In all cultural groups, rules and strategies exist to punish individuals that are perceived as disruptive for the group and undermining the social fabric (Boyd and Richerson, 1992, Boehm, 1999, 2000). These mechanisms range from mere gossip to ridicule to ostracism, all of which have dire consequences for such individuals in the kind of environment in which the hominid lineage evolved. If push comes to shove, capital punishment is also an option (Boehm, 1999). The major consequence of implementing punishment mechanisms is obvious: it sends a clear message to all would-be freeriders and alpha-type individuals that such behaviors are very costly in groups in which such rules prevail.

c) Rise of values and rules promoting cooperation within certain groups. As was mentioned before, social norms have two dimensions. They also include a positive dimension which amounts to encouraging certain behaviors. Just as such groups are willing to punish disruptive individuals, so they are inclined to reward individuals whose behavior is conducive to the group's well-being. This goes some way toward explaining why certain values and rules fostering cooperation and generosity can be observed in so many cultural groups. These values and rules typically have to do with things such as strategies for hunting, meat-sharing, the division of labor, sexual exclusivity, the raising of offspring, or some arrangements for taking care of the elderly, and so on. When such values and rules are promoted and become part of a group's ethos (Boehm, 1999), they clearly facilitate group-coordinated actions against freeriders and alpha-type individuals.

d) Transmission and reinforcement of these values and rules through cultural evolution (Boyd and Richerson, 1985, 2004, Chapter 6). A species that would modify its social ecology but that would not be able to pass on these changes to its offspring and future descendants would presumably have to start from scratch every generation. This is not the case for species possessing culture, most notably human beings. We see two main advantages to having culture in the context of our discussion. The first advantage is that it allows an accurate transmission of the rules and values prevailing in a group (both the positive ones geared toward cooperation and the negative ones pertaining to punishment) from one generation to the next. When cultural transmission happens, it amounts to engineering the social ecology of offspring and future descendants in this cultural niche. In this sense, just as Deacon made it clear with linguistic evolution (see Section 4), culture becomes its own selective pressure shaping the ecological niche of future generations. As Boehm (1999: 244) puts it, "*cultural traditions have their own strong effect. They are free to reinforce certain aspects of human nature, and to suppress others*." But that is not all. Not only does culture allow the transmission of certain crucial rules and values, but it also makes possible the reinforcement and improvement of such rules and values. This is the second advantage, namely, culture can *evolve* and accumulate the changes made to the social ecology. Tomasello (1999) refers to this process as the *ratchet effect*: just as much as it is possible for improvements in tools and weapons to be transmitted and accumulated, so it is possible for cultural changes and improvements to be passed on and accumulated, thereby engineering the social environment of future generations (see Boyd and Richerson, 2004). In short, cultural niche construction is often cumulative. Some examples of the cumulative improvement of cultural adaptations are given below in phase 3.

e) Emergence of conditions favoring group selection (Sober and Wilson, 1998). Though there is little empirical evidence supporting group-selection hypotheses in non-human animals, it is safe to surmise that the deck was stacked in favor of group selection in a species in which conditions (a) to (d) prevailed. Roughly, two of the basic conditions for group selection to occur in the Sober-Wilson model are satisfied in this scenario. On the one hand, the effect of having punishment mechanisms for freeriders is that it reduces *within*-group selection. In such groups it does not pay off to be a freerider or an alpha-type individual. On the other hand, rules and values promoting generosity and cooperation *enhance* between-group selection. This is also reinforced thanks to cultural evolution, which tends to favor conformism and imitation within groups (Boyd and Richerson, 1985, 1992, 2002). Together, these two conditions make it likely that cultural group selection played a central role in human evolution (Sober and Wilson, 1998).

5.4. Phase 3: The Presence of Social Norms in All Cultural Groups

This phase is the end product of this long process of cultural niche construction. It demonstrates the universality of social norms and goes some way toward explaining why social norms fulfill a similar function in all cultural groups. Let us briefly mention some of the final changes brought about by this Baldwinian process of niche construction:

a) Groups having established the values and rules mentioned in phase 2 are imitated by other groups. In a recent paper, Richerson et al. (2003) make a strong case for the idea that social norms spread from one group to the other thanks in part to imitation. Their group-selection inspired argument is that groups without such norms were not evolutionarily competitive vis-à-vis groups with such norms. It is indeed easy to imagine why groups with many freeriders are less likely to be cohesive and cooperative enough to compete against groups with little within-group selection. Accordingly, one of two possibilities seems to have been possible in that context. Groups outcompeted by cooperative groups were either merged to them; or they decided to imitate the cooperative groups by modifying their social ecology and implementing social norms. It seems to us to be plausible that they often adopted the second strategy.

b) Emergence of as a system ensuring the transmission of social norms and facilitating their application (Dunbar, 1999, Boehm, 1999, 2000). Language as we know it today most likely emerged late in the Paleolithic. Of course, language serves many purposes. But it is fair to assume that it facilitated the application and transmission of social norms. For instance, language is a reliable system of transmission. And in this sense it can be used not only to spread social norms to all members of the group, but also to future generations. Moreover, it increases the potential for a good coordination among members of cultural groups. Specifically, it makes it easier for a group to monitor the behavior of potential freeriders (e.g., they can set up a strategy while he is away). Language also increases the pace at which information is transmitted. And speed is of the essence when it comes to dealing with freeriders. A group might as well punish its freeriders before they even begin to disrupt the group; by then, it's often too late and within-group selection has taken over.

c) Institutionalization of social norms and formation of political and moral communities promoting cooperation and altruism. The creation of institutions designed to regulate and apply social norms is no doubt a recent invention in human evolution and a paradigm example of a cultural adaptation that is the outcome of a process of cumulative improvements. Such institutions range from legal systems to political systems to jails and police forces. The role of these institutions in fighting freeriders and alpha-type individuals is obvious. No society tolerates serials killers and rapists, for instance. Such institutions probably evolved hand in hand with the rise of political and moral communities promoting cooperation and altruism. Such communities go beyond simple rules of punishments and rewards, in that they sometimes have the ability to carry out an ethical and political reflection on themes such as the well-being of the group as a whole, equality, justice, fairness, and so on, which sometimes results in concrete measures taken to bring about social changes. In the best case scenario, that kind of reflection sometimes extend beyond the boundaries of one's own cultural group and focuses on the well-being of humanity as a whole, which is a kind of reflection that must have been totally alien to the way of thinking of our ancestors.

In the end, the moral of the story is that social norms are part of the social and cultural environment of all human beings. They are the outcome of a long process of cultural niche construction and are embedded in the developmental matrix of human beings, just as dams part are of the developmental niche of beavers. In this scenario, there is no *gene for* or *module* for social norms~~yet~~ such norms have become a part of human nature as language and sex. It seems to us that the basic Baldwinian insight~~a~~ mix of learning/plasticity and assimilation~~is~~ preserved in that scenario.

6. CONCLUSION

We would like to conclude by going over some of the most important conclusions reached in this paper.

First of all, the Baldwin effect is probably not as important a factor in evolution as Baldwin and Conwy Lloyd Morgan sometimes suggested, in particular when they opposed learning to natural selection and claimed that the former is the main mechanism driving the latter. The Baldwin effect is not an alternative to natural selection; portraying it in such a way may even partly explain why it has a bad reputation in some circles.

We also argued that genetic assimilation is not a requirement of the Baldwin effect; rather, the Baldwin effect should be construed in terms of niche construction, which is a process with an evolutionary dynamic of its own in organisms possessing culture (Odling-Smee et al., 2003). This new interpretation, while extending the Baldwin effect, nevertheless preserves its original insight, namely a mix of learning and plasticity on the one hand, and an assimilation of certain traits and behaviors into the developmental matrix on the other—that is, certain traits and behaviors become part of human nature without assuming that there is a specific set of genes, a module, or an instinct *coding* for such traits and behaviors.

Construed as niche construction, the Baldwin effect may not be the discovery of an entirely new mechanism affecting evolution by natural selection, as some enthusiastic 'Baldwin boosters'[11] may be inclined to think; rather, it is a process that has been neglected for way too long in evolutionary theory (Lewontin, 1983, Odling-Smee et al., 2003). Accordingly, it has a role to play in an extended version of evolutionary theory and is consistent with other approaches urging us to extend the framework of evolutionary theory, most notably multilevel selection theory and DST. Our approach is also consistent with *certain* theories of evolution in terms of gene-culture co-evolution, most notably that of Boyd and Richerson. For instance, in their work on the evolution of cooperation, Boyd and Richerson (Boyd and Richerson, 2004, see also Richerson et al., 2003) hypothesize that social institutions played a crucial role in the shift from *social* instincts to *tribal* instincts, a shift that paved the way for a greater degree of cooperation and altruism in humans. Clearly, the creation of such social institutions can be viewed as a typical case of cultural niche construction.[12]

If understood in terms of niche construction, the Baldwin effect cannot be reduced to natural selection, as though it was merely the product of the latter. Niche construction is very much part of the *process* of evolution by

[11] We owe this expression to Godfrey-Smith (2003), but he isn't one of those naïve Baldwin boosters.

[12] However, we would like to point out that other theories of gene-culture co-evolution are *not* congruent with our approach because they attribute a causal primacy to the genetic level of inheritance and downplay the causal efficacy of culture (see, for instance, Lumsden and Wilson 1981). Which is why we find the reference to theories of gene-culture co-evolution somewhat tricky.

natural selection. It has a causal efficacy of its own and thus co-contributes, with natural selection, to the evolutionary process (Odling-Smee et al., 2003). It is in this sense that it differs from a standard version of neo-Darwinism. Finally, construed in terms of cultural niche construction, it is very likely that the Baldwin effect played a fundamental role in the evolution of language and social norms~~and~~ possibly in the evolution of many other cultural traits and behaviors, which is why the extension of the Baldwin effect we proposed fits in with the *EEM programme*. The demonstration of this is the subject of another paper, however.

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Cultural creativity and evolutionary flexibility

Kathleen Coessens

Centre for Logic and Philosophy of Science,
Vrije Universiteit Brussel, Brussels, Belgium
kcoessen@vub.ac.be

Abstract

This article develops the philosophical idea that the cultural creativity and the evolution of the human being are both dependent on evolutionary flexibility. This thesis will be defended in three steps: starting with a short phenomenological analysis of the possibilities of the human being and its body (1), I will then examine theories and explanations of evolutionary flexibility (2) and finally I will explore how this contains the possibilities for cultural creativity and evolution (3). Both evolutionary developed features of the human being and its interactions with the environment are considered. The conclusion will be that the diversity and evolution of human culture awakens the dormant potential of this flexibility.

1. INTRODUCTION: THE ASTONISHING HUMAN BEING

What is the human being as an embodied being capable of? What are its possibilities, what are its limitations? Spinoza, already more than 300 years ago, was puzzled by these old questions, without providing a clear answer:

> Nobody so far has determined what the body's capabilities are, i.e. so far experience has taught no-one what the body might do and not do solely according to the laws of Nature, insofar as the latter is considered as exclusively body-related [. . .] it appears that the human body, through the laws of its own nature alone, is already capable of much that astounds the Mind itself (Spinoza, 1915: 132[1]).

The human being as a fundamentally embodied being seems to be a mysterious bearer of immense possibilities. The description of these possibilities has been the subject of various phenomenological analyses, going from Maurice Merleau-Ponty (1945) to Michel Serres (1999). In *Variations sur le corps*

[1] My translation, Spinoza, Ethics book III, proposition 2.

N. Gontier et al. (eds.), Evolutionary Epistemology, Language and Culture, 335–350.

the French philosopher Michel Serres describes the possibilities of the human body. Three aspects can be distilled from his work.

To begin with, he remarks that the human body is capable of an immense range of adaptations: from the desert to the poles, from the forests to the mountains, from aridity to monsoons: the human body adapts, endures, survives at the limits of endurable conditions. How many species colonize the whole space of the world, asks Serres and he answers *"few, only some mosquitoes accompany the human being, as well as bacteria"* (Serres, 1999: 50). The human being is the only mammal animal that has spread all over the earth, despite the variety of climatological and geological conditions. This extreme adaptability is not restricted to living conditions, but includes also actions and activities. Most animals set regular limits on their performances; but the human being can compel itself to defy all acceptable limits. As Serres mentions: the old man will run a 100 km in a few hours, while the adult male lion stops its course after 60 m, to catch its breath (Serres, 1999: 51). Endurance, force and power seem to be hidden characteristics of an apparently weak human body.

Secondly, the human body bears an immense reservoir of mimesis and metamorphosis. In which other species do we find clowns, acrobats, gymnasts, pianists? The human body varies and transforms attitudes, poses, gesticulations, exponentially through growing up, education, mimesis and role-playing. And in the process the human body acquires control, skills, techniques and it develops creativity. As Serres writes: *"The transformations of the human being, in fact, sometimes take unexpected ways that genetics did probably not anticipate: I could have been a pianist, practicing scales all day, but see how I am a watchmaker, repairing small wheels"* (Serres, 1999: 72[2]).

Thirdly, the human body is a bearer of creativity and creation: *"The body makes a body and the body makes a world. It creates the subject, it creates the object"* (Serres, 1999: 155). The phylogenetic development of the coordination of the brain, the eye and the hand has opened the way to the creation of objects. The development of the voice and the brain meant also the possibility of verbal creation and generational transmission. The cognitive possibilities for deduction, induction and abduction, metaphor and fantasy open(ed) new worlds of languages, concepts and knowledge. Starting from the earth and the earthly possibilities, the human being has, since its first existence, been continuously creating a world in which each generation invents new objects, as well as new variations on or new links between existing objects. Till now, possible destruction and natural entropy have not been able to annihilate this human creativity and expansion.

[2] All citations of Michel Serres is my translation.

So, what exactly is the human body capable of? Why can it do what it can do and how? Michel Serres explains nothing, he only describes, as most phenomenologists did before him; and Spinoza, puzzled by the same question, thought the question unanswerable. The question I want to answer in this article is the following: *How could these human body-bounded possibilities come about?* In order to answer this question, we have to throw a bridge between phenomenological descriptions and evolutionary hypotheses and investigate. As a philosopher, I will try to open some roads that I hope will trigger off a discussion for evolutionary theorists. The thesis defended in the next part is that the cultural creativity and evolution of the human being are dependent on some kind of evolutionary flexibility that exceeds a purely adaptational evolutionary schema. I will examine three theories that sustain this thesis. In part three I will then, with the help of these theories re-examine the phenomenological astonishment at cultural creativity and link them to some more philosophical and phenomenological theories.

2. EVOLUTIONARY FLEXIBILITY

Evolutionary flexibility implies that there are developments in evolution that defy strict adaptational laws. A very simple way to summarize Darwin's evolutionary theory is to take adaptation as its central concept. Adaptation is the basic principle that means that natural selection prefers evolutionary developments that are positive for survival in a specific environment and eliminates those that impede survival. Etymologically, adaptation~~as~~ *ad* + *aptus*~~me~~ans *going in the direction of*—*ad*~~an~~d *what is suitable*—*aptus*. Adaptation is a concept that describes the dynamic process starting from a basic earthy ontology to an evolution of living organisms struggling for their survival, because of changing environmental exigencies, with the basic rule that they must fit into their environment. Adaptation is functional, aimed at the survival of the species. But does everything that has developed and been maintained through evolution fit this mould? Are all features of living beings *adaptations*? Darwin himself was puzzled by some characteristics of living organisms that defy the concept of adaptation as immediate functionality or survival advantage: *" [. . .] organs of little importance, as affected by Natural Selection"* (Darwin, 1872: 144). Darwin gives the example of the sutured skulls of birds and reptiles: if sutures in mammal's skulls can be a beautiful adaptation for aiding parturition, it seems without advantage for birds and reptiles (Darwin, 1872: 145). Darwin himself realized that it is not possible to call this *adaptation*, at least not in the narrow sense. He had to resign himself to two conclusions: first, that not all variations that result out of evolution and selection are adaptive, i.e. functionally specified for some advantage for survival of the species; second, that not only adaptive features survive. Struggling with this, Darwin proposes the term *pre-adaptation*, suggesting that in the future these variations will be functional for survival.

More than a 100 years later Stephen Jay Gould again looked into the question first triggered by Darwin: How could something have been designed in advance for a future, not-necessary and/or non-existing function? The answer Gould proposes lies the term *ex-aptation*: i.e. an evolutionary developed feature, apparently suited for nothing~~or~~ at least for something that is of no immediate utility for survival~~co~~uld become suited for something, indirectly, in the future (Gould, 1991, 1998; Gould and Vrba, 1998). As Gould says: "*[...] built in the past either as non-aptive by-products or as adaptations for different roles*" (Gould and Vrba, 1998: 66). As long as these exaptations are not realized, not *in use*, they are pre-aptations: *"[...] potential, but unrealized, exaptations"* (Gould and Vrba, 1998: 64). The concept of exaptation as a complement to adaptation opens the possibility of a not solely functional, but also creative evolution on earth: there exists an exaptive pool, a reservoir of possibilities, which can be realized in three possible forms. Gould distinguishes, firstly, those features that did effectively suit an environmental claim, but that were also co-opted for another use; secondly, those features that were adaptive for a specific function on a certain level, but that had effect also on another level; thirdly, those features that never were adaptations for a specific function, but developed as structural by-products of other features (Gould, 1998: 661). This exaptive pool was contingently created by evolution in living organisms. The notion of exaptation opens an evolutionary view that includes flexibility, plasticity and contingency: *"all exaptations originate randomly with respect to their effects."* (Gould and Vrba, 1998: 67). Some features do not develop out of a selective determinism directly related to some specific functionality, but rather contingently; they bear multifunctional possibilities and effects, they can cause accidental side effects, they stay in the running, and are welcomed at another moment or at another level. Eventually, later on, they can take an important role in life-sustainment, or they can be realized as creative outputs that do not hinder survival, or can even be helpful for survival.

As such, by way of exaptational features, organisms themselves partake in a creative process of evolution, in a diversification of possible solutions to newly arising problems. After all, this seems analogous to effects in cultural life: a knife can cut, but some knives can be used toward other ends too for which they were not designed: as a screw-driver, as a marker, ... In biological life, the enzyme lysozyme, an adaptation that helped resist certain bacteria, turned out to have an exaptational quality, namely that of offering the possibility of lactation to mammals. Another example Gould offers, is the development of an internal skeleton: in evolution it originally served as a storage for phosphate, necessary for the muscular system, only to prove later on to offer the possibility of support and movement for mammals (Gould and Vrba, 1998: 57). Thus, as part of the organism itself, exaptations imply a fundamental flexibility that offers various possibilities, creative developments that can be realized later on, in different environments or in varying conditions.

Exaptations are thus one form of flexibility or even creativity in evolution. Such a richness of potentialities—resembling the Aristotelian concept of *dynamics*, i.e. potentialities that can be realized, but that are neither determined nor necessary in advance—is also present in Gibson's ecological theory of *affordances*. But here we have flexibility on the level of the interaction between living organisms and their environment. If evolutionary theory restricts itself to the adaptation of living organisms to their environment—and exaptations offer a possible adaptation to the organism itself—Gibson points to the fact that seemingly undirected and undetermined potentialities prevail in the exchange between organisms and environment (Gibson, 1966, 1979). Gibson calls these possibilities, enhanced by the relation between the environment and the organism *affordances*, because the environment *offers* elements to (human) organisms. The concept of exaptation remains a concept that refers to evolutionary evolved features that are or will be used or realized by and for the organism itself that happens to have these features, whereas affordances are features of an organism, an object or a material that are or will be used or realized by other organisms. Thus the relation between an *afforder*, an affording organism or element, and a *taking* or *receiving* organism is what prevails here.

What is this *affording* relation between an organism and elements of its environment? In the first place, it is restrained to what can be afforded and what can be accepted or assumed: objects, sensations and events. The human being reacts to and interacts with its environment. It takes those affordances it needs or encounters: *"An affordance is whatever a physical system can do in response to some human requirement"* (Harré, 1993: 46). The earthly environment affords a lot: air affords the possibilities of breathing, moving, visual perception, odor; water affords the possibilities of drinking, washing, sailing; the soil affords living organisms the ground for life, for standing, sitting, balance, place, movement and manipulation; trees afford shadow, fruits, energy, oxygen and carbon. Other persons and living animals afford rich and complex experiences, communication, sexuality, reciprocity, . . . and so exceed the purely biological environment *"What the other animal affords the observer is not only behavior but also social interaction"* (Gibson, 1979: 24, 130). The idea of affordance, for Gibson, is independent of its observer as well as of its realization:

> The observer may or may not perceive or attend to the affordance, according to his needs, but the affordance, being invariant, is always there to be perceived. An affordance is not bestowed upon an object by a need of an

> observer and his act of perceiving it. The object offers what it does because it is what it is. (Gibson, 1979: 139)

These affordances are most of the time sleeping or undetected possibilities, which can be aroused by some need, some event, some interaction with an observer and actor. As such, affordances offer an enormous creative pool of possible interactions between human beings and elements of the environment, that is neither determined, nor knowable in advance. These interactions are ecologically valuable, creative and inexhaustible. Think about a rose: it smells good, it is the sign of love, but also of socialism, it is an ingredient for food, cosmetics and drinks, it affords decoration and so on. Thus the concept of affordances can be widened from the biological to the cultural; and in this way affordances seem to be inexhaustible. I will return to this discussion in the third part of this text.

We can link Gibson's idea of affordances with exaptation in evolutionary theory. The concept of affordances broadens, from an ecological point of view, the idea of exaptation, and, more specifically, takes into consideration features that offer possibilities to other organisms in the environment, depending on contingent and interactional events. The rose was not designed by evolution for its good smell to be enjoyed by human beings, but its eventual adaptational utility can be broadened by an external exaptational feature, an affordance it offers other living beings. Note that the link between affordance and exaptation broadens the concept of exaptation much more than what Gould originally meant with it. Here, affordance, as a kind of externally oriented exaptation, refers to the possibility a feature can contain for other organisms, more specifically for the human being: food, protection, smell and so on. The three possibilities of exaptation Gould distinguished, are thus multiplied with this factor of an external organism that is offered or afforded something. Some features can be adaptations for the organism itself, while also offering exaptational possibilities for another organism; or they can be exaptations for themselves and exaptations for other living beings; or they can be exaptations for themselves, without offering any advantage for other beings.

We need the idea of affordances if we want to sustain the thesis of evolutionary flexibility, because the interaction between organisms, the exchange between different elements and living organisms offers another form of flexibility and thus possible contingency, leading to creativity. The interaction between the bodily, genetic possibilities and the affordance of the environment can so exceed the limitations of both the body and the environment. Clark refers to dolphins that can surpass their physical capacities of swimming by taking advantage of the environment: it is not only that *"By thus controlling and exploiting local environmental structure, the fish is able to produce fast starts and turns that make our ocean-going vessels look clumsy,* *ponderous, and laggardly"*, but moreover that *"it is even possible for a fish's swimming efficiency to exceed 100 percent"* (Triantafyllou and Triantafyllou, 1995: 69; Clark, 1999: 219). The concurrence of exaptational features in organisms with the affordances present in the environment, multiplies the possibilities of various life-forms and developments.

Gould's and Gibson's theories offer us some idea of features filled with potential creativity; one for the organisms themselves, the other concerning the interaction with other living beings. Varela, Thompson and Rosch propose a third, more comprehensive, theory that promotes a less *selectionist* and more *creative* evolution (Varela et al., 1991). These authors propose two principles that could sustain the concepts of exaptation and affordance. In the first place, they insist upon a proscriptive logic of evolution, not a prescriptive one: *"from the idea that what is not allowed is forbidden to the idea that what is not forbidden is allowed"* (Varela et al., 1991: 195). Natural selection remains the basic idea, but eliminates only what is not compatible with the survival of the species. The possible variety of biological structures that do not prevent survival, are not eliminated: if a feature does not disturb life, it can remain, and contain some creative surprise~~for~~ the proper organism it could be an exaptation, for other organisms, in a Gibsonian sense, an affordance. Unless environmental selection pressures are too strong, and unless adaptational needs are not met, useless, even inefficacious features can persist for a long time, and be outed for some utility, creativity or diversity later on. From this idea, the second principle ensues: the evolutionary process chooses solutions that are satisfying, not optimal; *"selection operates as a broad survival filter that admits any structure that has sufficient integrity to persist"*(Varela et al., 1991: 196). An increase of satisfying features will lead to an increase and a greater diversity of *viable* trajectories. Viability and underdetermination replace optimization and uniquely determined patterns in the evolution of species: *"much of what an organism looks like and is 'about' is completely underdetermined by the constraints of survival and reproduction"* (Varela et al., 1991: 196).

Natural selection becomes a principle resorting under the term *viability* and possible contingencies of biological evolution will have to cope with this viability. But if they do not prevent life, they can offer new sources for variety and creativity in evolution. Varela, Thompson and Rosch use an analogy to illustrate those principles. What does John do when he needs a new suit? He could go to the tailor for the exact and uniquely fitting dress, cut just for that special occasion. It would be the optimal solution for his need. But, as a common human being, he will search in clothes stores and choose between different existing suits. His choice will depend on different aspects and possibilities, exigencies and contingencies existing in his life-world and environment. The suit will not be the perfect suit, but if it fits him properly and satisfies him with respect to his life-world, he will keep it. The possession of that suit will fulfill his need without being an optimal solution: *"the very decision to buy a suit is not given from the outset as a problem but is constituted by the global situation of his life. His final choice has the form of satisfying some very loose constraints [...] but does not have the form of a fit [...] to any of these constraints"* (Varela et al., 1991: 194). We could further develop this analogy by saying that the suit will be used on other important occasions, or that it contains some important features for future uses, like some special pockets~~not~~ necessary for that first occasion~~but~~ just suited for that future mobile phone, or that the cloth will be remodeled in another form or cut up for shorter pants or used as a theatre costume, or that the suit will fit another person as well. The suit will contain a lot of exaptational possibilities and offer a lot of affordances for organisms, and will exceed its original necessity.

Gould's evolutionary exaptation, Gibson's ecological affordances, integrated in Varela, Thompson and Rosch's proscriptive logic of evolution open up the possibility for *creative*, unexpected features to emerge in evolution or to be realized later on, depending on the natural or cultural environment, and depending on the interaction between organism-related exaptations and environment-related affordances. If they do not hinder the necessary adaptation for survival and reproduction, they can be part of the evolution. Thus, they could not only offer a possible explanation for the evolution and the diversity of species but also for the emergence of culture and for the diversity in and of cultures.

3. CULTURAL CREATIVITY

Can we now link these theses concerning biological and ecological theories to the further development of a cultural evolution? It is by trying to do so that we can find an evolutionary explanation for the astonishing possibilities of the human body, as described by Michel Serres.

The question of how natural and cultural evolutionary lines are linked remains a difficult one. How was it possible for the human being to develop culture? This was only possible if there existed a species endowed with a complex cognitive apparatus supporting this, allowing this. As Richerson and Boyd write: *"there cannot be complex traditions without the cognitive machinery necessary to support them"* (Richerson and Boyd, 2000: 342). In this line of thinking, a flexibility allowed by natural and genetic evolution should sustain a possible human evolution to cultural capacities.

Richerson and Boyd describe a first evolutionary adaptation of mammals, a growing brain, to altering climatological conditions (Boyd and Richerson, 1985, 1995; Richerson and Boyd, 2000). They further suppose this to be a pre-adaptive development of the arising human being: *"its evolution required, as a pre-adaptation, the advanced cognition achieved by many mammalian lineages in the last few million years"* (Richerson and Boyd, 2000: 344). Tomasello, Dunbar, Adolphs and others sustain the idea of a social brain hypothesis to further round out primate and human evolution (Dunbar, 1993, 1998, 2000; Barton and Dunbar, 1997; Adolphs, 1999; Tomasello, 2000; Brothers, 1990). This implies that the brain may have developed further under pressure of social exigencies: *" primate brain evolution has been driven principally by the demands of the social world rather than the demands of the physical/environmental world"* (Dunbar, 2000: 206). Thus, a big brain was more adapted to the living conditions~~at~~that moment social ones~~than~~ previous brains. Group size, the ability to manipulate information about social relations themselves, intentional behavior and the capacity of a theory of mind~~be~~ing aware of and interpreting or understanding the states of mind of others~~are~~ what the hypothesis of a social brain is about. If we follow this social brain hypothesis, we have a possible evolutionary explanation for a highly complex social life, but does this allow for all the cultural creativity and diversity humans have brought about? It is one thing to be capable of manipulation, interpretation and intentionality concerning social behavior; but quite another to explain the complexity of the human cultural world. The difficulty of proving the existence of a social brain beyond complex social behavior~~and~~ allowing it to explain culture in the broadest sense~~is~~shown in the fact that evolutionary theorists try to limit their researches to the more primitive, hunter-gatherer human society. What can we say about our ability to create computers, poetry, art, varieties of cooking and clothing?

The natural and biological evolution of the human being must have been an evolution that allowed for undetermined possibilities, for flexibility and creativity: an adaptation to variable environments was needed. Sustaining the social brain hypothesis already points in this direction, but not as far as to explain all this. Other explanations, be they ecological, developmental or epiphenomenal, explain even less. They only point to the evolution of a growing brain. The human being must be endowed with a plasticity that accepts a multifactorial interplay between genes, ecological and social environment, including the influence of culture~~ho~~wever, diverse the latter may be, from a hunter-gatherer society to a highly technological and complex geopolitical society.

But let us recapitulate. On the one hand, we have noted that the human being is a natural being, endowed with capacities for culture. As Ingold writes: *"The total independence of genetic and cultural transmission is difficult to accept, if only because the capacity to acquire cultural information is genetically encoded, but not vice versa"* (Ingold, 1986b: 364). It is impossible to keep those two lines separated, if only because natural evolution has given at least the possibility to develop sophisticated social and later on cultural abilities.

On the other hand, once a cultural evolution evolved in addition to a biological one, a continuous interaction between both started taking place:

> The history of the human species has been brought about by interactions of biological and cultural variables; it is just as futile to attempt to understand human biology if one disregards cultural influences as it is to understand the origin and rise of culture if one disregards human biological nature. (Dobzhansky, 1951: 385 in Cole, 1996: 165).

Recent neurological research sheds some light on this debate. As the neurologist Edelman notes, not only the quantity of the human brain has been altered by natural evolution, but also its quality (Edelman, 1987; Reeke and Edelman, 1988; Edelman and Tononi, 2000). Could not the quantitative growth of the human brain have made possible new qualities: the appearance of an immense possibility of unexpected, underdetermined features, that could be co-opted into the cultural evolution of the human being? Might not the human brain be understood as an immense vat of exaptational features? Was cultural development originally allowed by the contingencies of a proscriptive evolution, by a host of acquired features, sleeping potentialities, seemingly frivolous or hidden properties that remain and are kept on board, since they do not obstruct survival? And indeed, could not the apparent gap between the biological evolutionary and the cultural evolutionary be spanned by the theoretical idea of exaptation, more precisely concerning the effects of exaptation of the human brain and body? And could not affordances of all kinds contingently have opened the way for diverse and complex use and creation in the world?

Gould himself refers briefly to the broadening of the application of exaptation to human and cultural constructs, beginning in the brain and widening to the whole cultural domain: *"The human brain is, par excellence, the chief exemplar of exaptation"* (Gould, 1991: 55). The idea of qualitative possibilities of the human brain set forth by Edelman can give us a possible answer. Reeke and Edelman researched the plasticity of the human brain and its development in the first years of the human being. They found that the human brain is fundamentally and originally underdetermined:

> there is not enough information in the DNA to specify uniquely the locations of all these neurons and their connections. Thus indeterminate, dynamic, epigenetic mechanisms (mechanisms reflecting the influence of the local environment on the unfolding genetic programs of individual cells) must operate during development to determine the fine structure of the nervous system (Reeke and Edelman, 1988: 156).

In Edelman's neuronal group-selection-theory, the phylogenetically developed possibilities fit into the ontogenetic development and maturation of the human brain and nervous system. Roughly, this means that culture fills in some of the possibilities of nature. His theory starts from a fundamental adaptation of the human body and brain to a relatively changing and polymorphic world. The potential basis for organization of and adaptation to the environment is the presence of numerous groups of cells in different parts of the brain that are variants of each other. This variability guarantees potential organization of the environment: a first prenatal arrangement will be followed by a second or postnatal arrangement when the individual shows attitudes of observation and interaction. Further selection continues by means of the influence of the experiences, the contingencies of the environment, on the human being and by his exchange with his environment: *"We manage our physical and spatial surroundings in ways that fundamentally alter the information-processing tasks our brains confront"* (Clark, 1999: 65). This excludes models and structures that are strongly predetermined (Gosselin, 1995). The result is that every top–down pre-disposition, be it genetic, modular or other, is always tributary to bottom–up impact and shows some flexibility.

The theories of Edelman and Reeke sustain and explain what Gould had in mind (Reeke and Edelman, 1988). Skoyles further rounds out the concept of exaptation in a similar sense (Skoyles, 1999). Biological evolutionary flexibility makes cultural creativity possible. The human nervous system has an enormous plasticity and leaves open an immense potential of different functions. Nervous channels, suited for eyesight, are used by blind people for more accurate hearing and finger-reading. Young children under four can, after severe injury of parts of the brain, continue their normal development because other parts of the brain just take over tasks to avoid a loss of function (Gazzaniga et al., 1998). Hands are not designed to play the piano, though the plasticity of the brain makes this activity possible for any ordinary human being. The human brain contains a vat of exaptations: an immense pool for coping with unexpected situations, complex events, different cultures, varieties of non-innate skills: *"Because of this such noninnate skills were transmitted across generations, and thus resulted in early humans developing the rudiments of a material and symbolic culture"* (Skoyles, 1999: 438–439). Skoyles, in a further reflection on Gould's exaptation, is convinced of the flexibility of a lot of evolutionary features of the human being: *"neural plasticity, in a period too short for natural selection to have operated, has been co-opted for another important function: enabling brains evolved for life in simple hunter-gatherer bands to live in agricultural and hi-tech complex societies"* (Skoyles, 1999: 438–439). This flexibility proved to be positive in adaptational terms, but at the same time, it went much further than a functional adaptation and opened up creative exploitations. Both Gould and Skoyles refer to all elements of cultural performances of human beings as the products of exaptational features. The human being has the fantastic faculty to create exo-somatic elements—the term is Karl R. Popper's (1972). These are elements that function as complements or extensions of the human mind and body. This faculty exists also in the animal reign but is exponentially developed in the human kind. We do not need better eyes: we can wear glasses!We have not developed faster legs: we invented bikes and airplanes. Our constraints of memory, physical force, mobility and lifespan, are met by computers, books, weapons, cars, pharmaceutical innovations and all other products of human knowledge. This development originally emerged from nature, from an untouched environment, but then builds on preceding, previously realized exosomatic development. As Andy Clark (1999) says in his book *Being there: putting brain, body and world together again*: it is a process of *external scaffolding*. Thus, neural plasticity has opened the way for coping with new functions and~~cu~~ltural~~evo~~lutions without the urgent necessity of new adaptations through natural selection.

Neurological research fits Gould's and Skoyles' hypotheses that language, religion, art and script could be exaptational realizations. Language may not be the product of natural selection, but a side effect, resulting from the increase of and modifications in the brain (e.g., Chomsky, 1968, 1975, 1986; Gould, 1991). I will not develop this thesis further~~it d~~emands a lot more information~~bu~~t I will just raise here the idea that language could be the result of a combination of several exaptational and adaptational features.[3]

Edelman's neuronal theory strongly supports the notion of some evolutionary flexibility, while at the same time it confirms from a scientific point of view older phenomenological and social theories concerning the world-openness of the human being. This philosophical idea of *world-openness* was formulated in the early 20th century. When Berger and Luckmann wrote in the 1960s *"man's relationship to his environment is characterized by world-openness"* (Berger and Luckmann, 1966: 65) they were echoing the German philosophers Arnold Gehlen, Max Scheler and Adolf Portmann. These men ascribe the world-openness of the human being to its premature birth (Gehlen, 1961). The fundamentally helpless newborn is unfinished, immature and necessitates an extra-uterine development that other animals acquire already intra-uterus. This helplessness is absorbed by an open world full of impressions and events, risk and noise, feeling and surprise, and not, as with other animals, by the closed darkness of the uterus. That implies a far greater impact of a very complex environment on the human being: the plasticity of the premature human being can develop, because of the presence of an open world, into an openness toward this world. Such an early relationship with the

[3] Thus, it could possibly link some very divergent theories about the evolution of language, e.g., the motor theory of language, body-linked theories about metaphorical use and modular-and brain-system-oriented theories. The motor theory sustains that the structures of language (phonological, lexical, and syntactic) were derived from and modeled on the pre-existing complex neural systems which had evolved for the control of body movement (Deacon 1997).

environment goes beyond the imperfect possibilities of the biological composition of the human being (Berger and Luckmann, 1966: 56). The human being, in spite of its frailty, can cope with extremes because of its flexible adaptability, its inherent openness to a complex and open world. Such theories of world-openness further influenced pragmatism and existentialism, from Dewey to Sartre. Today, neurologists such as Edelman demonstrate scientific, neurological translations of this already existing philosophical idea, thereby showing that it offers not only a philosophical but also scientific standpoint against evolutionary and genetic determinism and strict modularism. Following this hypothesis, only a soft version of modularity can be accepted, with innately specified modules next to self-organized maps, and in which even those modules can be remodeled by self-organization originating in life-experiences. Research into evolutionary correlations sustains this: *"adult neocortex size in primates correlates with the length of the juvenile period, with the 'software programming' that occurs during the period of social learning between weaning and adulthood"* (Joffe, 1997 in Dunbar, 1998: 185).

World-openness is one philosophical way to circumscribe exaptation, or we could also call it a cultural description of the result of a proscriptive evolution that allows for some contingency and creativity. These exaptational possibilities, realized as flexible adaptational means for coping with the contingency and complexity of the environment, and characterized as world-openness, open up a wide access to cultural development and diversity.

Thus, from a philosophical point of view, we can draw a line going from evolutionarily developed exaptational features to their realization, not only for some ulterior needs for biological survival, but also finally as creative manifestations that at first sight exceed pure survival, or, in one word, as culture. The human brain has developed to a very complex, flexible organ that performs much more than specifically survival tasks. Apparently, natural selection gave the advantage to a brain that was premature at birth but, precisely because of this, also extra-ordinarily flexible. This plasticity set in motion a domino effect: creating and acting in the world resulted in creations and acts that could be passed on and explained to the following generation with these premature, flexible brains. The human environment and this brain make for a cumulative effect: cultural objects and attitudes evolve, develop, become more complex, are changed. This is what is called the *ratchet effect*: the effect by which skills, rites, languages and knowledge are transmitted and are, under the influence of the environment, received, increased, renewed, modified by further human generations: *"Once elementary complex traditions exist, the threshold is crossed"* (Richerson and Boyd, 2000: 343). It is the ratchet effect that could link biological exaptational features to cultural exaptational realizations, and ecological affordances to cultural affordances. The ratchet effect is the ulterior human development~~or~~should we say the ulterior exaptation~~of~~ a social brain evolution. From that moment on, the cultural world with its theories, arts, objects, languages and so on, contains an array of new possible affordances that defy each new human being.

4. CONCLUSION

If, originally, natural evolution implied the possibility of developing a cultural realm, nowadays we can say that cultural evolution~~in~~ terms of technology and science~~in~~fluences further natural evolution. Both lines are definitely linked. In the West the cultural development of genetics, of technology and general knowledge, has an increasing impact on the natural evolution of the species on earth. The way we live, eat, spoil, changes ourselves and our environment profoundly. We are becoming capable of cloning individuals of some species, of genetically modifying plants, of eliminating survival-threatening features and repairing bad genes. Our understanding of the impact of our cultural actions on the natural evolution of our world and on its living species—including ourselves~~re~~mains unclear and incomplete, but that it has an impact makes us powerful as well as fearful. As a philosopher, I remain indebted to Gould's open worldview explained in his last book, *The structure of evolutionary theory* (Gould, 2002): flexibility and creativity in evolutionary theory allow room for some choice, individuality and creativity: preeminently essential human features, even if this implies making errors.

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Some ideas to study the evolution of mathematics

Hugo Mercier

Institute for Cognitive Sciences, Lyon, France
hmercier@isc.cnrs.fr

Abstract

Evolutionary psychology can shed light on mathematical abilities. To do so, it must be supplied with a strong model of cultural evolution. Natural selection endowed us with some modules, like the number sense or the logical module, useful for mathematics. Then cultural evolution tinkered with them to create modern mathematics. Of particular significance during cultural evolution is ancient Greece, where a feedback loop that stressed the importance of formal proofs was engaged. Ever since, mathematicians have been engaged in a quest for relevance that uses formal proofs as an indicator of relevance. This led to modern mathematics. Nonetheless, mathematics relies on cognitive mechanisms that were empirically acquired during phylogenetic evolution, and this explains their 'unreasonable effectiveness'.

1. INTRODUCTION

This chapter belongs to the large (indeed) enterprise of evolutionary epistemology. It throws some ideas as to how mathematical skills evolved and try to analyse the evolutionary mechanisms involved. Because it relies on phylogenetic and cultural evolution, it is somehow between the evolution of epistemological mechanisms and the evolutionary epistemology of theories programmes. Culture and language are both given an important place in the proposed view. Together they supposedly managed to turn cavemen into members of the Bourbaki group, primitive cognitive modules into amazing mathematical skills.

So the aim of this chapter is to show how an evolutionary analysis can be useful to study the way we do mathematics. This can be quite surprising: evolution deals with survival and reproduction, doesn't it? How manipulating quaternions could help me thrive and have kids? My remote ancestors knew nothing of them, and they did quite well. Mathematics must be a purely cultural product of some civilizations, most developed in the west during the last centuries.

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There are a lot of problems with an extreme cultural view of mathematics, the first one being the numerous convergences observed in civilizations that had no contact. Pythagoras' theorem was separately discovered by at least Babylonians, Greeks, Chinese and Indians. Those resemblances can be readily explained if we posit the same cognitive apparatus for would be mathematicians all around the world. Obviously, differences in exact formulation of theorems, or the degree of mathematical refinement attained are to be found among diverse cultures. Far from undermining the evolutionary view, I shall argue that they can be envisioned as experiences helping us to uncover our shared cognitive abilities. More on this later.

Admitting common capabilities to cope with mathematics is admitting that they are a legacy from evolution (if not, where could they come from?). However, this opens other interesting questions. First of all, are they adaptations, by-products or just the result of some chance processes? Those hypotheses have all been supported for another high-level activity: language. The by-product hypothesis, i.e. that language is derived from other adaptations, was supported by the late Stephen Jay Gould. Noam Chomsky, quite surprisingly, once argued that it was just a product of some mysterious physical mechanism among our neurons, given that there are so many. But now, adaptationist theories are growing, and even if we are far from a consensus about what the function of language is, more and more people agree that it has one (or several) function, and that it evolved gradually by natural selection (Pinker and Bloom, 1990; Jackendoff, 2002). To be clear, we need to introduce a distinction similar to the one between the Language Acquisition Device (LAD) and language. What adaptationists are saying is that the LAD is an adaptation to learn language, which is itself adapted to communication. If we posit a MAD (Mathematics Acquisition Device), we could say that everybody shares it, and that its product (mathematics) differs among different communities, as language does. But mathematics, as we practice them now, is very different from language. Perhaps is it closer to linguistics than to language: it is a formal science that needs a long and difficult training (indeed). Quite the opposite of natural language. Moreover, among different cultures we can observe huge differences of complexity in mathematical practices. Conversely, differences in the complexity of languages are reduced. So the MAD cannot be a strict equivalent of the LAD, because in this case we would expect the same properties in language and mathematical skills. It seems more sensible, and this is the idea I will develop in this paper, to posit that mathematics are based on a bunch of cognitive devices which are more or less expressed depending on the culture you belong to. Among these cognitive devices, some are close to basic mathematical capabilities, and others are very distant. How do they work together? The hypothesis is that culture can plug some cognitive adaptations into others, so that the end product is nothing that natural selection would have ever dreamed to produce. In some groups, cultural evolution managed to recruit our cognitive mechanisms in such a way as to produce modern mathematics. So the distinction between adaptation and by-product can be split into two questions:

(1) are those cognitive devices adaptations or by-products? And,
(2) what is the status of novel, culturally acquired capacities? If they are based on adaptations, but that their product is new, and not explicitly designed by natural selection, they are in between. At this second level, the dichotomy adaptation/by-product blurs and loses its relevance.

As we begin to see, we will need to study both our evolutionary legacies and what culture can make of them, how it can turn a gazelle hunter into a Fields Medal laureate. To do so, a good method must be chosen to study the evolution of the human mind. The first part will try to show the respective advantages and drawbacks of the different propositions that have been made in the last 30 years. As cultural evolution will also play a big role, the second part will be dedicated to it. Next, some proposals will be made as to which modules, shaped by evolution, can be useful to the practice of mathematics. Those modules will have a more or less direct connection with mathematical abilities as such, so the fourth part will be dedicated to the way cultural evolution linked all those elements to create a professional mathematician. Last but not least, some suggestions will be thrown as to how the evolutionary view can help to disentangle some philosophical problems.

2. PHYLOGENETIC EVOLUTION

Since the 1960s, different propositions have emerged as to the use of evolutionary theory to unravel the mysteries of the human mind and behaviour. To summarize, after E.O. Wilson's monumental and controversial *Sociobiology* (Wilson, 2000), we find several more or less related descendants.[1] First, memetics and gene-culture co-evolution (GCC). Both are related to Wilson's later work with Lumsden (Lumsden and Wilson, 1981), which aimed at integrating cultural and genetic evolution. Richard Dawkins launched memetics, with the core idea of considering cultural elements, or memes, as self-replicating entities somewhat similar to genes (Dawkins, 1976, 1982). This approach faces several problems, the worst one being its psychological implausibility: we do not copy the representations in other minds, but each

[1] These approaches have been thoroughly reviewed by Kevin Laland and Gillian Brown. (Laland and Brown 2002), but I will take a less neutral stance here.

representation has to be reconstructed by means of inference (see Sperber, 2000b). These mechanisms render the comparison with genes quite tricky: remember the last course you followed, would you say that the teacher's ideas were reproduced in your mind with a 10^{-6} mutation rate? Perhaps memetics will develop, if effectively amended, but at any rate, it does not have enough empirical results to be really useful yet.

Gene-culture co-evolution was developed independently by Cavalli-Sforza and Feldman, and by Boyd and Richerson (Cavalli-Sforza and Feldman, 1981; Boyd and Richerson, 1985). As memetics, it relies on theoretical, mathematical models of evolution, but it combines the effects of genetic evolution upon cultural evolution, and vice versa. GCC can count some rare empirical studies, and its models are more refined than those of memetics, but they both share the same flaw: lack of grounding in psychology. They fail to take advantage of the huge advances done in cognitive science. As for now, they are not easily applicable to any practical case, and we will not consider them any further.

The two other heirs of sociobiology are human behavioural ecology (HBE) and evolutionary psychology[2] (EP). HBE is the more direct successor of sociobiology. It sees human behaviour as a way to maximize fitness. Our mind should be designed so as to produce behaviours that help us transmit as many genes as possible to the next generation, by means of direct reproduction or by helping our relatives. Some of its practitioners are anthropologists, and their method has been cast the counting babies approach, which is quite explicit. However, this method does not seem appropriate for the case at hand. One can hardly see how the average mathematician promotes his genes by computing complex numbers. Even discarding extreme cases like Hippasos or Evariste Gallois, brilliant mathematicians do not seem to show a particular reproductive success. Anecdotal evidence apart, HBE has a more fundamental flaw: its agnosticism concerning cognitive mechanisms. That is where EP enters the play.

Evolutionary psychology has its roots in sociobiology and in cognitive psychology. It tries to combine them in its own way, to surmount the deficits of each approach. From sociobiology, it retains the evolutionary stance, and its huge heuristic power, but it discards the emphasis on behaviour to put it on cognitive mechanisms. From cognitive science, it retains the experimental method, and all the advances in the scientific study of the mind, but it discards the 'intuition and instinct blindness' (Cosmides and Tooby, 1994).

[2] Here I limit the use of evolutionary psychology to what has been dubbed the Santa Barbara School. Founded by Donald Symons and precisely defined by Leda Cosmides and John Tooby, it contrasts with broader uses of the name EP to regroup all the different approaches to the evolution of the human mind and behaviour (for an example of such a broad use under the banner of human evolutionary psychology, see Daly and Wilson 1999; Barrett et al., 2002).

By ‘intuition and instinct blindness’, evolutionary psychologists mean that their colleagues used to rely on mere intuition to find the function of cognitive mechanisms. Evolutionary psychologists try to compensate this by exploiting Darwin’s theory as a very powerful heuristic. They view the mind as a set of modules (close to the Fodorian meaning, see Fodor, 1983), each one having been designed by natural selection to perform a particular task. Those modules are adaptations. This view is known as the Swiss army knife model of the mind.

Here we already have two quite contentious claims: (1) the mind is a set of modules and, (2) they are adaptations shaped by natural selection. I will take a humble view on both points, and argue that they may not be the ultimate truth, but that they are the most valuable heuristics we have by now. First, modularity. If we journey back to 1983, Fodor denies modularity to central systems on the ground that they are, among other things, isotropic and Quinean. This leads to the conclusion that, to put it bluntly, we will never know anything of them. However, the a-modularity of central cognitive processes has been challenged by proponents of massive modularity (e.g. Sperber, 2001, 2005). They propose to discard some of the more exacting aspects of Fodorian modularity (such as strict innateness or mandatoriness), in order to apply it to all cognitive processes. This allows modules to be culturally modified and avoids most of the difficulties of more classical modules. Moreover, neuroscience used to offer arguments against modularity, but by now a more or less modularist interpretation takes the edge (see, e.g. Marcus, 2004). So, if modularity is neither psychologically nor neurophysiologically implausible, I do not see any good reason to deprive ourselves of its huge heuristic power. As Fodor himself repeated in his recent book: *“The real appeal of the massive modularity thesis is that, if it is true, we can either solve this problems* [with viewing cognition as computational]*, or at least contrive to deny them center stage pro tem”* (Fodor, 2001: 23).

Secondly, adaptation. What is the advantage of characterizing cognitive mechanisms as adaptations? Well, as already mentioned, it gives us clues as to what their function is. In David Marr’s very useful framework (Marr, 1982), it is indispensable to know the goal of a cognitive device to understand the way it works. Without the Darwinian stance, we are left with our intuitions. But a lot of fuss has been made around the adaptationist programme.[3] It has been forcefully assaulted by Gould and Lewontin more than 20 years ago, and some of the scars are still visible (Gould and Lewontin, 1979). One of their points was that it is always possible to create a new adaptationist theory

[3] It corresponds, more or less, to the statement that organisms are somewhere near the optimum.

that will fit the facts, and, therefore, they are just-so stories that cannot be falsified. There is truth in this idea. One can always think of another adaptationist account. However, each of those accounts is testable, and discarded if it does not fit the facts. So, even if the adaptationist programme in itself is not testable,[4] each and every sub-proposition it makes is testable, and scientists all over the world devote their time to do exactly that, Gould and Lewontin warnings notwithstanding (Alcock, 2001). As much as others evolutionary minded scientists, evolutionary psychologists are well aware of the numerous constraints that preclude organisms from being perfect (Dawkins, 1982; Maynard Smith et al., 1985). They know that natural selection has a limited bearing on a lot of what happens in evolution (genetic drift, founder effect . . .). Nevertheless, they use the adaptationist stance because it is the only one, as for now, (1) to have such a heuristic power and, (2) to easily yield testable hypotheses.

So should we just take the EP framework and try to carve mathematics at its joints? No, because its treatment of culture is far from sufficient. Perhaps was it foreseeable, since both its parents somewhat share this drawback. Sociobiology was fiercely assailed by anthropologists for its simplistic view of culture. Cognitive psychology, despite the cultural penchant of some of its initiators (e.g. Jerome Bruner), tried to maintain cultural phenomena apart, and considered cultural variations of cognitive mechanisms as mere quirks. Classically, EP distinguishes between evoked and transmitted culture (Tooby and Cosmides, 1992). Evoked culture is just another way to adapt to the environment, and is directly triggered by it. Transmitted culture, on the other hand, propagates by means of imitation and communication. It is based on the Sperberian epidemiology of representations (Sperber, 1996). Happily, things are evolving.[5] The birth of cognitive anthropology, and recent work by mainstream cognitive psychologists (e.g. Nisbett et al., 2001) are beginning to show (1) that cognition is indeed relevant to the study of culture and, (2) that cultural differences can have strong effects on cognitive mechanisms.

Here, I will expose a different way to mix cultural and phylogenetic evolution, one that gives more power to cultural evolution than what is usually consented in EP. Instead of seeing culture as a kind of stuff that fills in the boxes designed for it in the mind, I will argue that it can change the respective importance of the boxes and of the links between them.

[4] Which it may very well be, at least in the case of other animals, see Orzack and Sober (2001). For humans, I am quite dubious that it can ever be really tested on any grand scale.

[5] In later works, Cosmides and Tooby seem to use a more elaborate vision of culture as "the serial reconstruction and adoption of representations and regulatory variables found in others' minds through inferential specialisations evolved for the task." (Cosmides and Tooby 2000: 55) With this definition, the distinction evoked/transmitted culture fades away. However, this dichotomy is still a textbook example (Buss, 1999) and is still worth criticizing.

3. CULTURAL EVOLUTION

In a very broad view of evolution, it is useful to distinguish three time scales: phylogenetic evolution, cultural (or historical) evolution and ontogenetic evolution. Clearly there is a lot of interaction between those three time scales. Some tried to model those interactions, most notably in the framework of gene-culture co-evolution, but this approach remains too far from cognitive mechanisms and empirical tests for our present purpose. Among the authors who gave a more empiric look, we should note Tomasello's work (see Tomasello (1999) for a summary). With his colleagues, he developed a very fruitful research programme of comparative studies between human children and apes. In his theory, most differences between us and the apes rest on the ability to "'identify' with conspecifics, which led to an understanding of them as intentional and mental beings like the self." (Tomasello, 1999: 10). Given the very rich social environment in which human children develop, it allowed them to acquire a lot of skills and knowledge from other people. This, in turn, triggered cultural evolution and its cumulative properties (the ratchet effect). Tomasello's theory has an undeniable aesthetic appeal, partly caused by its apparent simplicity, and is backed up by a lot of data. However, I think it rests on a disputable premise carried on by a disputable assumption. The disputable premise is that human uniqueness rests mainly upon *one* cognitive ability. Trying to force all human particularities into one mould will always lead to somewhat far-fetched theoretical scaffoldings. Say that a new and powerful ability arises in our remote ancestors. Given the opportunistic character of natural selection, it is hard to figure out why it would not take advantage of this new toy to tinker with it. New cognitive devices drawing on this one could evolve. Moreover, the arms race principle could lead to the evolution of ripostes and counter-attacks. Tomasello's answer is that we did not have time to do all this. For him, natural selection did not have enough time since the splitting of our common lineage with apes, some millions years ago, to fine tune several important cognitive abilities. He uses this argument against classical EP and its host of new modules. This is a very disputable assumption. The relationship between genes (the only material with which natural selection can directly play), brain and mind is far too obscure for us to be so secure about any conclusion. Some researchers maintain that the very quick human brain expansion is fully compatible with modularity and adaptationism (e.g. Marcus, 2004). If we let the assumption aside, the premise is no longer justified hence it should be abandoned.[6] Instead, I propose that we use a broadly Sperberian framework.

[6] One might answer that Tomasello's theory, being simpler, remains preferable on aesthetic grounds only. However, I find it very unlikely that a unique (or even a small cluster) of ability

This framework accommodates modularity and cultural variation. Seeing the mind as a bunch of fixed and mandatory computational mechanisms faces several problems. Some are technical problems: how to explain conceptual integration or context-sensitivity. They have already been answered (Sperber, 1994, 2005). But modularity also seems to be at odds with cultural variation. So we are caught between two fires: on the one hand we must deal with computational constraints, and this usually leads to modularity and domain-specificity (Hirschfeld and Gelman, 1994); on the other hand, we must account for the huge diversity of human culture, and the behavioural flexibility we typically display. To solve both problems, we need something like a modularist anthropologist, but they are a rare breed. The framework getting nearer to the solution is probably Sperber's. In a few lines, here is how it explains cultural variation with a modular mind. The first important element is the distinction between proper and *actual* domains. The proper domain of a module is the kind of input it evolved to compute. If a fear-of-spider module existed, its proper module would be real spiders. The actual domain of a module is what it actually takes as input. Our imaginary fear-of-spider module could take spiderlike bugs as input. Natural selection cannot calibrate exactly the input domains of the different modules, hence some mismatches are bound to appear. The size of the actual domain compared to the proper domain depends of the relative importance of false positives and false negatives. This mismatch could be amplified in humans, at least because some of our modules were explicitly designed to deal with highly variable information (social or contextual for example). This could lead to modules now being used for quite different purposes from the one they evolved to fulfil.

This idea can be expanded in at least two directions: the creation of novel modules and the alteration of the functioning of existing ones. For the later, we can propose a distinction between proper and actual processing. Along the lines of proper and actual domains, this partition reflects the fact that modules cannot function exactly as natural selection has intended them to work. Depending on the course of development and local environment, modules should show differences in the way they process information. Richard Nisbett and his collaborators have shown a host of differences in the processing of information between easterners and westerners~~ev~~en at a low level (e.g. Nisbett et al., 2001; Nisbett, 2003). Those differences seem to be consistent with the different systems of thought and of social organization found in the east and the west. In all the experiments reviewed, inputs were similar but were processed in different ways depending on the group to which the subject

will ever account for the gap separating us from the apes, so if there is no scientific reason to prefer the *one ability* solution, I think we should reject it.

belonged. Hence the functioning of modules can be significantly altered while remaining efficient. What of the creation of brand new modules? If we let aside the innateness requisition for modules, we can consider culturally created ones (Sperber, 2005). Reading is a paradigmatic case: it looks like a module, but cannot be innate. Stanislas Dehaene proposed a neurophysiologically plausible account of the way a reading module could be created, by "selection and local adaptation of pre-existing neural region" (the so called visual word form area) (Dehaene, 2005). A module is probably never completely novel in the sense that new capabilities cannot emerge *ex nihilo*, with absolutely no bases. In the case of reading, we needed abilities to see and differentiate small patterns. A part of the visual system specializes in the recognition of letters during development because letters are such an omnipresent and important part of our environment. However, this sub-module has taken such importance and is so different from its basic form that it might be better to call it a novel module. In a similar way, connections between modules can be reinforced when they are often used, leading to unanticipated results. Again in the case of reading, not only the visual word form area but also its link to the semantic memory must be particularly developed in literate persons. We thus have several mechanisms capable of modifying the input of modules, their functioning, the link between them, and even of creating novel ones. I would now like to stress the purported mechanisms driving cultural evolution.

So modules can change. Very well but why, and in which direction? If it was just for random evolution due to ecological variation or chance processes, it would be quite surprising that some modules evolved to give us something as complex and coherent as modern mathematics. We need not explain the apparition of modern mathematics *ex nihilo*, but we need to explain why every step that led to them was in the direction of more complexity and coherence. For Sperber, the force driving cultural evolution is the search for relevance during communication. What is it to be relevant? To be relevant is to produce in the listener the greatest cognitive effect for the least cognitive effort. How can this be achieved? By activating the different modules, i.e. aiming at their domains. Given that we are such a highly communicating species, the input of some modules will soon consist in a lot of transmitted information instead of information acquired by yourself. When I tell you stories about animals that contain interesting information, you will listen to me, and it will save you the pain of checking that lions are dangerous. A lot of modules will soon see their domains extended in unprecedented ways: they will acquire a *cultural* domain. Inputs falling in this domain are different from others in the actual domain because they were deliberately created by other human beings to engage such or such module. Back to our fear-of-spider module. Some of us now live in a quite spider free environment. So the module is hardly ever activated by inputs falling in its proper domain. However, stories about spiders are exciting and movies with spiders frightening (even if not good, admittedly). All those fake spiders belong to the cultural domain of the fear-of-spider module. They have a different status from a spiderlike bug (actual domain) because they were designed by other human beings to fill in the input conditions of our fear-of-spider module. Pascal Boyer has devoted much of his work to show how religious beliefs can be explained: they usually fit into one of our modules (naïve psychology, naïve biology, naïve physics . . .), which make them understandable, but blatantly contradict one expectation (e.g. a human that can pass through the walls), which make them interesting and rememberable (Boyer, 2001). A very important point about relevance is its context-dependence. To be relevant is to be relevant in a given context. If you transmit already known information, you will not give rise to a great cognitive effect. I will now give a brief account of some of the modules with which cultural evolution can tinker to produce modern mathematics.

4. SOME MODULES USEFUL FOR MATHEMATICS

When Andrew Wiles elaborated his demonstration to Fermat's Theorem, he must have used a host of different modules. Some of those are very low-level: motor control for writing, vision for reading and so on. Others are more sophisticated, but still quite basic: number sense, spatial representations and mental imaging, etc. Some are high-level ones, like metarepresentations or language. It would be a colossal enterprise to enumerate them all. Here, I will just choose some of those modules and try to see why they evolved. Some will seem quite unrelated to mathematics, but the next part will be dedicated to show how culture can put them together to produce novel mathematical outcomes.

4.1. Number Sense

Instead of reviewing several basic capabilities useful for mathematics, the number sense will be used as an example.[7] It will show the diversity of resources on which EP can dwell to investigate modules. First, comparative studies. Rats required to press a lever a particular number of times, then another lever, are able to count up to 24. They can also count the number of

[7] The part on the number sense is based on the numerous previous reviews. See: Hauser and Carey (1998), Wynn (1998), Butterworth (1999), Dehaene (1999), Hauser and Spelke (in press).

paths before turning in a maze (like when you take the fourth alley on your right). Experiments with canaries, raccoon and other animals show that a more or less developed number sense is widely shared. Closer to humans, studies on rhesus monkeys and cotton-top tamarins show that they can add or subtract small numbers of items. Even closer, chimpanzees are able to categorize items based on the fraction they represent (a quarter of an apple with a glass a quarter full). One of their conspecific, dutifully trained, was even able to associate the Arabic numerals 0–4 to the quantity they represent, and make basic operations with them.

Another field that has provided a lot of evidence for domain specificity, and is, therefore, a golden land for evolutionary psychologists, is developmental psychology. The number sense is no exception. Karen Wynn conducted groundbreaking studies showing how clever infants are with numbers. Using the habituation paradigm, she showed Mickey dolls to infants (aged four and a half month and older). First, a doll is placed in front of the baby then a screen hides it. A second doll is then brought behind the screen, and the screen is dropped. In the experimental condition, only one Mickey is left, and babies are surprised (they look longer at the lonely Mickey than when there are two of them). Babies also find faulty subtractions funny (Wynn, 1992).

Several mechanisms have been proposed to account for this number sense. The most fashionable seems to be the accumulator model. An accumulator is filled by a kind of pacemaker, with a switch allowing it to be filled only at specific times, and for a chosen duration. The quantity is represented by the countenance of the accumulator. This model accounts for a lot of experimental evidence. It explains for example why we, as other animals, are much better at estimating small than large quantities. Among the hypothesized functions of this basic number sense, we find its utility for foraging (choose the tree with the most berries) or for tracking sets of objects (when three lions are running after you, it is not a good idea to stop when two of them have lost your track).

However, this is far from sufficient to explain even basic mathematics. Abilities to deal with spatial representation, for example, are also required. Some reasoned that those abilities partly evolved to help us foraging, finding the way to edible berries or tracking wild game (Silverman and Eals, 1992). More generally, abilities to exploit mental imagery must have been very useful for a broad range of tasks (Shepard, 1987). Surely other less explored abilities might count as basic mathematical skills.

4.2. The Cheater Detection Module and the Natural Frequency Module

I will now turn to two modules explored by mainstream EP: Gigerenzer's natural frequency module and Cosmides' cheater detection module (CDM).

Both take place in the context of the psychology of reasoning, where it has been fashionable to show how poorly human beings reason. Kahneman and Tversky made a long standing attack against our ability to make proper Bayesian inferences. When people are presented some kind of problem and asked to give an estimate of a posterior probability (e.g. given such and such information about a given disease and a given person, what is the probability for her to be ill?), they fail to take into account the base rate (e.g. 0.1% of the total population has this disease), committing the base rate fallacy. However, Gigerenzer and his colleagues showed that if the problems are presented in the proper manner, the subjects can become very good at the same task. Instead of giving them probabilities in the form of percentages, they gave the subjects natural frequencies (e.g. 1 out of 1000 instead of 0.1%). In this new format, people manage to take into account the base rate and obtain good results. Gigerenzer claims that this is due to a mental algorithm dedicated to the calculation of natural frequencies (e.g. Gigerenzer, 1998). Percentages and other sophisticated probability formats being unavailable to our ancestors, they had to reason with the observed number of cases (e.g. such thing happened X times out of Y occasions it had to happen). To function, this algorithm obviously needs to count events or things, and to operate basic calculations. So it could take as input some very basic mathematical abilities and turn them into something much more powerful.

Studies on the CDM were launched by Cosmides' 1989 paper (Cosmides, 1989). She used the Wason selection task (the most studied task of the psychology of reasoning) to show that people are very good at looking for cheaters.[8] Her evolutionary argument follows these lines: (1) as a species, we engage in a lot of social interaction and exchange; (2) a likely explanation for these altruistic acts is reciprocal altruism (Trivers, 1972); (3) it can be modelled using computer simulations, where a strategy called Tit for Tat wins repeated prisoner's dilemma (Axelrod, 1984). Finally (4) both reciprocal altruists and Tit for Tat need a way to recognize cheaters, otherwise they cannot function. So natural selection must have endowed us with a Darwinian algorithm able to recognize this special kind of wrongdoers: the CDM. A cheater is defined as someone who takes a benefit without filling the associated requirement. As for the natural frequency module, it will often rely on the number sense, for example to determine a proper cost/benefit balance. Even if the CDM in itself does not yield new mathematical abilities, we will see that it might serve as a drive to elaborate novel mathematical instruments.

[8] Unhappily, the CDM still finds its main support in the Wason selection task and it faces strong problems of methodology and interpretation (e.g. Sperber et al., 1995). Before we can be sure that the CDM exists, more evidence will have to be gathered.

4.3. Language

All the capacities described so far can probably be found in other animals.[9] I will now give a brief look at two of the cognitive abilities that distinguish us from other animals, namely language and metarepresentations. The evolution of language is one of the hottest topics in human evolution at the moment. As succinctly stated in the introduction, more and more researchers agree that human language is an adaptation, but there is no consensus as to the way it evolved. It must have increased the fitness of the most talented orators among our forefathers, but how? We sometimes give valuable pieces of information to potential contenders in the struggle for reproduction!We do not only speak to our close relatives; neither do we strictly apply reciprocal altruism, so two of the favourite explanations for altruism are ruled out. Perhaps the answer lays in two allied principles: sexual selection and the handicap principle. Both are advocated by Geoffrey Miller, and his argument boils down to this sentence of Woody Allen in *Hollywood Ending*: "talk is what you suffer through so you can get to sex".[10] More precisely, language is a good fitness-indicator: people who speak movingly, eloquently, with humour or in a poetic way must have good genes, because those abilities are very susceptible to genetic variation or accident. The handicap principle is supported by Jean-Louis Dessalles (Dessalles, 2000). Here are his main points: (1) we are a political species, where coalitions and alliances are very important; (2) the coalition leader(s) enjoys a better reproductive success; (3) to become a leader, one as to display capacities useful for the coalition; (4) among these is the ability to gather relevant information and (5) language renders the display of this very ability possible by allowing us to share information with others. To put it bluntly: we are speechifiers. Sexual selection and the handicap principle are not mutually exclusive, and they probably both explain some of the advantages gained thanks to language. The problem of those models is that they are too far from linguistic reality; they fail to predict the main features of language. Models of the evolution of communication are far from being well understood (Maynard Smith and Harper, 2003) and it is too soon to settle for any specific hypotheses. I just highlighted the two aboves, because they could explain some feature of

[9] It is unequivocal for the number sense and mental imagery, and we can imagine that the calculation of something akin to natural frequencies might be useful to a range of animals. For the CDM, perhaps we could find an equivalent in species practicing reciprocal altruism (such as some kinds of blood sharing bats).

[10] Obviously this does not make justice to the complexity of Miller's though. See Miller (2000) for the real account. He does not claim that language as a whole evolved by sexual selection, only its more gratuitous aspects, like our huge vocabulary apparently devoid of any direct use.

language potentially important for the example of cultural evolution proposed here.

Anyway language indubitably evolved, and its advent played a huge role in human cognitive evolution. Natural selection probably tinkered in two ways: from pre-linguistic cognitive abilities to create some parts of the language capacity, and from the newly formed language capacity to enhance other cognitive devices. Concerning mathematical abilities, if we start from the number sense, it must have aided the construction of quantifiers and numerals. The comprehension of words like *a lot of*, *some*, or *more* probably rely on some non-linguistic capacity to deal with quantity. With others words, they might have formed the vocabulary for relational concept, a postulated element in the evolution of language (Jackendoff, 1999). Once language was acquired, it could help the number sense. The accumulator upon which it relies soon becomes inaccurate: it distinguishes two from three readily, but with 27 and 28, the matter is much trickier. Experiments with humans and animals show that as the numbers grow, the estimation becomes more and more imprecise. Here language can be of invaluable assistance: it allows us to create different words for each number, so we can distinguish and operate calculations with them much more easily (the link between language and number sense is quickly explored by Hauser and Spleke (in press)). As a cognitive tool, language can be useful in a lot of other ways, but I will not belabour the point and I will go to its other huge role for mathematics: communication.

Communicating "propositional structures over a serial channel" (Pinker and Bloom, 1990: 712) is a proposed proximal function of language. How can this help the development of mathematics? Clearly modern mathematicians would not go very far without an important learning phase for which language is indispensable (spoken or written; even Ramanujan draw inspiration from a book). They have to discuss their results, whether directly or by means of publication. They share their ideas, debate . . . We would indeed be hard pressed to imagine how mathematical thought might have arrived where it is without language. But knowing *that* language is used for mathematics does not explain *why*. Why do mathematicians speak of Zermelo-Fraenkel set theory with choice rather than of the beautiful potential mate over there?[11] Any evolutionary minded scientist should wonder why mathematicians (and other scientists, including himself) devote so much time speaking about something apparently so remote from reproductive success. This question yields at least two answers, a general and a particular one. The general one rests on the EP framework. Evolutionary psychologists often explain non-fitness enhancing behaviours by the fact that our minds were specifically designed

[11] Admittedly, both are not incompatible, but why do they *also* speak of ZFC?

for the environment of evolutionary adaptedness (EEA).[12] Our modern world being considerably different, some non-adaptive conducts should, therefore, be expected~~It~~ can explain, for example, that some otherwise successful mathematicians remain celibate. But it crudely underdetermines mathematical thinking: why should anyone engage in such a sophisticated and complex enterprise when there is a lot of easier ways not to be adapted? A lot of the remainder of this paper will be dedicated to the particular answer, but before we can continue to explain why some of us do mathematics, we need some more explanations about how it is possible. So we now turn to one of the other human novelties: metarepresentations.

4.4. Metarepresentations and the Logical Module

As humans, we engage in an awful lot of metarepresenting activity. Classically, we read other minds, thanks to our theory of mind (aka ToM). To do so, something like that has to happen in our minds:

Gosh, why does Julie think that	[first level of representation]
I have finished the chocolates.	[second level of representation]

ToM is among the most studied example of metarepresentations. However, Cosmides and Tooby (Cosmides and Tooby, 2000) propose that they play a much larger role in our minds: to keep some representations apart from others (see also Nichols and Stich (2003) for a broader review of the problem and some criticisms). Why should we quarantine some representations? Because if we don't, we risk to mix true things with suppositions, falsehoods and fictions. In the example above, admit (however hard it is) that I have *not* finished the chocolates. I am nevertheless able to conceive that Julie thinks that I have done so. For the two propositions (that I have not finished the chocolate and that I have finished the chocolate) not to clash, they must be kept apart, and this is the role of the embedding in "Julie thinks that ...". This inclusion prevents the first representation from interacting with other representations. This reasoning applies to a lot of cases: when you desire a meringue and plan to go to the bakery, neither the goal nor the course of event are realized (yet). When you listen to a storyteller, you know her tale is unreal. When, as a child, you pretend to be mommy, you know you are not her. Very often do we need to embed a representation into another. Those metarepresentations can be considered as different kinds of tags, which indicate the truth condition of

[12] The argument is that since the dawn of agriculture, 10,000 years ago, there has not been enough time for important evolution by natural selection to take place, so our minds were designed for an environment roughly spanning from a few millions years ago to 10,000 years. Hence the slogan: "our modern skulls house a stone age mind".

a representation, the moment when something happened, the person who said or thought something, etc. This ability distinguishes us from most animals: they are naïves realists. True is the basic state of all their representations, so they do not even need to be tagged. It probably also is the basic state for our representations. By isolating suppositions, stories, goals, other's thought, etc. from other representations, it allows us to think of something as *false*. Without this ability, you would clearly not go very far in mathematical practice. However, if this ability is necessary for mathematics, it is far from sufficient. As for language, it allows complex mathematical thought, but radically underdetermines it. We will get nearer with the last relevant module that I wish to highlight: a logical module.

In a pragmatic view of language, understanding an utterance involves a lot of metarepresentational activity. You have to infer the communicative intention of the speaker. In relevance theory, this is achieved by means of inferring the most relevant interpretation of the utterance given the context (Sperber and Wilson, 1995). These are the normal and indispensable metarepresentations that we have to compute in order to communicate. However, perhaps are we also endowed with other, more specialized, devices. Sperber (Sperber, 2000a) postulates the existence of a logical module, aimed at checking the consistency of others' utterances, and at giving ours appearance of consistency. What is the evolutionary justification for such a module? It is quite straightforward: language, being such a powerful communicative tool, is a potential lethal manipulation weapon. Imagine that you were to believe everything people tell you. You would soon find yourself ruined and doing some nasty works for other people (if still alive). There is a number of ways not to fall into this pit. One could trust only his family, or his friends. At least, we surely grant people with different degrees of trust. One could also rely on supposed cues to lying, such as abundant sweating or numerous hesitations (but we seem to be quite bad at that, see Ekman (2001)). A general solution is to check the external and internal consistency of what others tell you. Lying is not easy: the liar has to be careful (1) not to say anything that clashes with what is already known by the listener and (2) not to state two things incoherent with each other. Perhaps the first task (checking external consistency) is already achieved by our normal inference mechanisms for comprehension. But the second task has to be carried out by a specialized logical module. Roughly, it takes the output of the language comprehension module as input, and checks its internal consistency.[13] But this is only the first step: once you are protected from others' lies, perhaps you could try a little manipulation yourself . . .

[13] Admittedly, we lack empirical evidence for the particular form of this module. Experiments are under way.

You have this brand new module, which enables you not to be fooled by average smooth talkers. Why not try to use it to take advantage of your fellow man? By using logical relations and new words designed to express them (*if* ... *then, hence, therefore* ...), you might be able to convince others. You could gain a little advantage. Nothing very important, but it can allow you to take the edge in discussions. Given the importance of language in our species, this is all but trivial. Soon an arms race will engage, with people becoming cleverer and cleverer at breaking others' fallacies and devising more and more convincing arguments. This phenomenon would stop only when the computing costs outweigh the benefits of being hard to fool. The end product might be a quite powerful logical ability applied to the content of what we hear and utter. It could allow us to follow and devise complex rhetorical arguments. Stressing the importance of logical thinking in mathematics would be ludicrous. However, at prima facie, this ability doesn't apply directly to mathematical arguments, and cultural evolution will have to play a linking role.

What do we have so far? A number sense to estimate large quantities and count precisely small ones. Capacities to deal with mental imagery. Some modules to calculate important results, but in very limited domains. Language, which helps us to think and to share the products of those thoughts. An ability to metarepresent propositions, so that we can think of them as false. A logical module to check the internal consistency of utterances and devise logical ones. Surely a lot is missing but this will allow me to sketch a story of how cultural evolution tinkered with these elements and created modern mathematicians.

5. APPLICATION TO MATHEMATICS

What was the state-of-the-art before the first recorded cultural invention related to mathematics? On the one hand people talked, using their modules for language comprehension, and their logical module to devise and understand rhetoric. On the other hand, they had this number sense ability that allowed them to count up to small amounts and estimate bigger ones. The first link between those two sets of abilities was the use of words for numbers. It is hard to decide whether they belong to the cultural or the proper domain of the number sense. During production, we can surmise that the number sense feeds the language production module, and during comprehension, the output of the language comprehension module is fed into the number sense, so that we can estimate the quantities that words represent. This link probably partly evolved by natural selection, but only in a very rudimentary form. That is, the proper domain of the number sense was likely to widen to accommodate words for number as a new kind of normal input. However, the huge differences in the number of words for numbers found across cultures seems to indicate that beyond the first words, the others belong to the cultural domain of the number sense.[14] Anyway, words for numbers could then be processed by the logical module, via our language comprehension or production modules. This gave our ancestors the possibility of devising the first rudiments of mathematics. But why would they do so? Probably for practical purposes, like keeping count of game killed or guarantying the fairness of exchanges. Trade is not new indeed. Archaeology and anthropology points to traditions of trade that may be as old as modern human beings (Ridley, 1996: 197 and *passim*). In order to make good deals, one has to keep track of quantities, and sometimes to operate basic operations with them. If one axe is worth four spears, then one shall not be happy to exchange his two axes against six spears. Here we meet again the CDM. If we follow Cosmides' argument and accept that we are endowed with a set of mechanisms for dealing with social exchange situations, then they could provide the urge for a great deal of mathematical advances. Recall that the CDM computes costs and requirements. They can consist of a single act or a single good, but they can also consist of repeated acts or of several goods. In this case, the unaided number sense would soon show his limits (e.g. the fact that it quickly becomes inaccurate). Language could be used to precise the numbers involved in the transaction. But as soon as language is used to establish the terms of the contract, the logical module enters the play. It would be very tempting to try to fool the other into believing that he is concluding an honest deal while you are duping him. And it would be very useful not to fall into that kind of trap. Thus the first mathematicians might have been swindlers and would be swindlees. The invention of cognitive artefacts (i.e. objects that help us to think) and the further advances of mathematics will confirm this trend.

Thirty-seven thousand years ago, someone made 29 notches on a baboon's fibula. This is the first cognitive artefact created for mathematical purposes. What did the anonymous carver intend to keep track of, we will never know. But we know for sure that these notches belonged to the cultural domain of her number sense. They were intentionally created to fit in the domain of the number sense: they were an icon for the number 29. Thanks to this bone, a number could be indefinitely kept in memory and passed on with no communication mistakes to anybody. Calculations were made easier. But this is nothing compared to the next big step: the invention of writing, the cognitive artefact among all. Writing allows the storage of huge quantities of information

[14] The fact that we find a particularity (words for small numbers here) in every culture needs not mean that they are innate; they may just be a Good Trick upon which every culture stumbled at least once (Dennett, 1995). However, as already pointed, the emergence of a new module or link between modules *ex nihilo* is quite unlikely, so I prefer the explanation that relies on the reinforcement of existing links or modules.

and their unaltered transmission across generations. For the (then few) literates, this invention meant an explosion of their cultural domains. Their language comprehension module was no longer fed only by oral input, but also by written one. The same scheme that occurred for the oral language could be repeated with all the advantages provided by writing. Whereas the first cognitive artefacts (notches in bones) fed directly into the number sense, written symbols had to pass by the language module. In its turn, the language module, aided by the number sense, can give a meaning to the numerals (e.g. the quantity 'six' for six), and feed the logical module with it. So the logical module could now work with written symbols for numbers. With this new technique at hand, Babylonians devised advanced mathematics. One point is worth stressing here: all their algebra was expressed in words. They solved equations using rhetoric. This is a nice example of a direct application of the logical module, designed to do just that—rhetoric, for mathematics. Why did Babylonians devote so much work to mathematics? Their purposes can be divided into two groups: a more theoretical tradition dealt with astronomy and astrology, and a more practical one with finance, measurement, etc. I will not try to explain the mechanisms underpinning religious beliefs here, but Pascal Boyer has done so in a framework close to the one used here. Anyway, they sure are a force that can motivate people to do mathematics. For example, if your religious beliefs grant an importance to the cycles of the moon, it would be relevant to devise a way to predict the next full moon. As for the more practical purposes, a lot of them can be explained by the same urge we described above: to establish honest deals. To give but one example, Babylonians left us sophisticated tables of inverses, squares and cubes, used to calculate interest rates. We find a similar pattern among Egyptians, with mathematics relying heavily upon religious beliefs, but also well designed for practical purposes. Their system of unitary fractions gave them precise results, much more useful than approximations when it comes to the sharing of an inheritance or the exchange of goods with no money available. Then we meet the Greeks, who avowedly owed a great deal to Egyptians, but who revolutionized mathematical thinking in their own particular way.

What is so special about the ancient Greeks? They were the first to do mathematics just for mathematics, with no practical use in sight. This probably came from their taste of formal proofs and sound logic. To explain these tastes, Richard Nisbett compiled the views of philosophers, historians and sociologists (Nisbett, 2003). He explains how some particular ecological and economical conditions led to a distinctive kind of thought. One of his conclusions is that due to those conditions, ancient Greeks were endowed with a strong sense of agency. They were very conscious that they were individuals, with their own view of the world, which could be quite different from their neighbour's. And instead of trying to reconcile those different views of the world, they had a tendency to think that their own was better, and to try to convince the neighbour that he was wrong. This lead to their taste for public debates and arguments. Hence the development of rhetoric, and even of formal logic: "[Aristotle] *is said to have invented logic because he was annoyed at hearing bad arguments in the political assembly and in the agora"* (Nisbett, 2003: 25). This last point is particularly interesting for us, and I will try to see in more detail what happened. When you must evaluate an argument or try to refute it, you can check its internal or its external consistency. Apparently, the Greeks favoured the former, and this can be indirectly tested. If we surmise, with Nisbett and his colleagues, that modern Western populations show some similarities with the Greek system of thought, we can go and test them. That is what they did (Norenzayan et al., 2000), studying differences in the strength of the belief bias between Western and Eastern populations. The belief bias is the tendency to believe in a logically invalid conclusion that is plausible, and not to believe in a logically valid conclusion that is implausible. It is a measure of the relative importance given to internal coherence (validity of the deduction) versus external coherence (plausibility of the conclusion). They found that belief bias was weaker for Westerners. Hence internal consistency was favoured. And it is the logical module that is in charge of checking the internal consistency. This is only one argument (and an indirect one at that) but others can be found in the literature reviewed by Nisbett that show how much the Westerners (hence Greeks also, if we pursue this line of reasoning) rely on the logical module. More precisely, that means that if you wanted to be relevant in this context, you had better devise arguments that pass the test of the logical module. To do so, one can carefully design valid deductions, and this gives Aristotelian syllogisms. But the logical module is not error free, so one can create demonstrations that merely look logic but are flawed and this gives sophistic. Anyway, soon the proper domain of the logical module is overwhelmed and those new logical forms develop its cultural domain. The important thing is that each increase in the cultural domain of the logical module means (1) new standards of relevance if others want to interest and/or trick you and, (2) the ability to meet those standards yourself. When you learn new logical tricks, you are not impressed by them anymore, but you can use them to impress others. In a world where being logical plays an important part in being relevant, this process sets a positive feedback loop in motion: To be more relevant you devise new logical effects, after a while others get them, and they have to devise still new tricks, and so on and so forth . . . up to modern logicians and their complex logical systems.

More precisely, in the feedback loop described above, two mechanisms can intertwine: arms race for manipulating the other and quest for relevance. The former is identical to the mechanism that promoted the logical module during our phylogenetic evolution: you devise more and more complex logical tricks for manipulation and defence against manipulation. The latter relies on a different mechanism: it is a by-product of your tendency to seek relevance while communicating. In the special context created by the Greeks, if you wanted to be relevant, you had to create new ways to aim at the domain of the logical module. This second phenomenon most likely played a more important role in cultural evolution. Concretely, it means that when someone devises a new advance in logic, it is not directly to manipulate his colleagues, but to impress them with the relevance of his invention. In this context, you had to respect the constraints imposed by the logical module, but that does not mean that you were restricted to it in your quest for relevance. Roughly, when you try to be relevant by taping in the logical module, you have three choices: (1) use your logical module to be relevant in another domain. That is what the Babylonians did: they used their number sense in conjunction with their logical module (in the form of rhetoric) to solve equations of algebra, and they did so because the results obtained where relevant for commerce, astrology, etc ... (2) You can also design new logical effects that will be relevant for the logical module, and only for him. That is what the Greeks did when they invented formal logic. And, (3) you can use different inputs to feed the logical module in order to attain new levels of relevance for the logical module. When those other inputs come from modules related to mathematics, you obtain formal proofs of mathematical statements.[15] To summarize: *"Science, in this view, is an extension of rhetoric. It was invented in Greece, and only in Greece, because the Greek institution of the public assembly attached great prestige to debating skill.* [...] *A geometric proof is* [...] *the ultimate rhetorical form."* (Cromer, 1993: 144, quoted in Nisbett, 2003: 37–38) This created a new context in which not only did you had to respect the constraints of the logical module, but also the intuitions coming from other modules. Being relevant in this context meant devising formal mathematical proofs that were new and respected all those constraints. A positive feedback loop, similar to the one that occurred for logical thinking, may now engage. It led to the expansion of the cultural domains of several modules, including the number sense and the logical module, and the reinforcements of links between those modules, up to modern mathematicians. Moreover, remember that for Miller and Dessalles at least some features of language evolved as a means to display our abilities. This would give another rationale for the quest for relevance: not only would we seek relevance for the sake of efficient communication, but also to boast. If this were to be true, we could analyse the respective part played by those two processes in cultural evolution in general, and in the historical evolution of mathematical thought in particular.

[15] And when other inputs are used, perhaps does it lead to Western philosophy ...

So the answer to the question asked in the third part (why do we speak of quaternions or ZFC?) would be something like this: The forces of cultural evolution tinkered with our phylogenetic legacy, creating a set of formal mathematical knowledge; some individuals acquire parts of this set during ontogenetic development, and this creates a context in which their urge to be relevant will lead them to speak of quaternions or of ZFC.

6. SOME TENTATIVE PHILOSOPHICAL CONSIDERATIONS

In the framework of the philosophy of mathematics, where would those ideas fit? The more direct relevance of this proposals would probably bear on the 'unreasonable effectiveness of mathematics', to quote Eugene Wigner. To explain that, I will claim that mathematics are somehow empirical. I will begin by explaining how all the abilities we need to do mathematics were empirically acquired during our phylogenetic history. This is quite straightforward for the number sense and other basic capacities. They result from the innumerable experiments made during evolution. We can consider each new genetic change (mutation, duplication ...) as a new experiment. Natural selection plays the role of the scientist: it sees which experiments work, and keeps them. What is the epistemic value of this process? We can assume that it is advantageous for organisms to be accurately informed about the environment they live in. Natural selection deals with the statistical regularities of the environment. If you place an organism in an environment in which one plus one always equals two, and if the capacity to understand such a relation is useful and cognitively accessible, then natural selection will probably endow the organism with the expectation that one plus one equals two.[16] The same is probably true of mental imagery: it would be quite useless if it did not reflect some properties of the world. To quote Roger Shepard: *"The universality, invariance, and elegance of principles governing the universe may be reflected in principles of the minds that have evolved in this universe* [...]" (Shepard, 2001: 581).

Things get more indirect with the logical module. Here is how it relates to the external world: (1) As seen above, our perception and inference mechanisms should usually yield accurate information about the world. For the sake of the discussion, I will call this information true information. (2) When we communicate, we generally wish to communicate true information, but we can also try to fool others by communicating false information.[17] (3) The

[16] The problem is then: can we ever be *sure* that natural selection endowed us with abilities that exactly reflect the world? I am quite pessimistic about the answer, given that the very capacities we use to search for it are also legacies from evolution.

[17] Admittedly, we can sometimes manipulate by telling the truth, or advantage someone by lying to him, but I take for granted that these cases are exceptions.

logical module evolved to sort out these two kinds of information. Therefore, it has an epistemic value. The logical module could be compared to a control system that checks the output of another instrument. Hence even if its relation to the world is indirect, it is there nonetheless. Moreover, the logical module should be quite efficient at sorting true from false information, because the non-efficient logical modules were selected out as their owners were duped. So we can say that the logical module has an epistemic value empirically acquired.

But even admitting that those abilities were somehow empirically acquired during our phylogenetic evolution, one might say that this does not explain the whole edifice of modern mathematics. Obviously not, this is why I described a possible route of cultural evolution leading to modern mathematics from these abilities. The point I wish to make now is that every little piece of mathematical knowledge can be traced back to our more basic abilities. To explain this, I will take a very sketchy example. Let’s imagine two hypothetical human beings endowed with all the modules needed, but with no cultural knowledge on top of it.[18] That is, no part of the domains of their modules is cultural. They begin to talk, and they try to be relevant. To do so, one of them uses his abilities to devise an utterance that, once understood by the other, will fall into the cultural domain of one of his modules. The second one then uses his abilities in conjunction with this new knowledge to devise an utterance that will, in its turn, fall in the cultural domain of the first character. The mechanism of the feedback loop engages, and they acquire bigger and bigger cultural domains. The important point here is that every little advance can be traced back to the initial, bare modules. Our two protagonists have children. As they grow up, the children quickly see their cultural domains widen at a far more important rate than the ones of their parents. They take cultural evolution were their parents had left it, and the same mechanism engages. But even in this case, every single piece of knowledge possessed by the descendants can be traced back to the moment it was first created. Our ancestors invented more and more efficient ladders to step on the shoulder of giants (from notches in bones to encyclopaedias) but the basic mechanism remains the same. More formally put, it would give something like: The initial modules are symbolized by X
Our first individuals just had XThen, using these capacities, they devised the first Y, i.e. the first cultural invention. Y is entirely explainable in terms of XThey went on and from XY, devised Y’, which is entirely explainable
in terms of XY. From XY+Y’, they created Y”, and so one and so forth.
Now we have an awful lot of “ ‘ “, and not only Y, but also W, T, J . . . but in theory (not in practice, admittedly) we can explain each new component in terms of its antecedent, and so go back to the bare modules.

[18] They are hypothetical indeed. Cultural and classical evolution interacted for some times, but I don’t think this would really interfere with the argument.

What are the conclusions? That mathematics, even advanced ones, is somehow derived from abilities that were empirically acquired during our phylogenetic history. So maybe their effectiveness is not so unreasonable. I am even tempted to say that it is more interesting to take the problem in the other way around: what can the effectiveness of mathematics tell us about their evolution? This leads to a different, somewhat weaker, version of the indispensability argument: (P1) cognitive mechanisms of which products are good at explaining the world, particularly those related to science, must have evolved to efficiently reflect some aspect of the world; (P2) the cognitive mechanisms underlying mathematics yield products that are not only good, but probably indispensable to understanding the world; (C) therefore, the cognitive mechanisms underlying mathematics must efficiently reflect some aspect of the world. This argument confirms the above statements about the number sense and the logical module. It is particularly relevant for the logical module: the fact that logic, in conjunction with other abilities, yielded so many important results in science, may be used as a good indicator that the logical module has an epistemic value, i.e. is quite good at sorting out true from false propositions. This whole argument could give credence to the idea of some mathematicians that mathematical or logical ideas can be evaluated by their efficiency. For example, in the battle around the excluded middle, some have claimed that they prefer to stick to this principle because it is indispensable to huge branches of mathematics, some of them used in science. This very fact might indicate that the excluded middle principle is a component of our logical module. And if it is really the case, then perhaps it is here for a good reason: because it reflects some property of the world.

However, one should be very cautious with this kind of claims, and investigating other cultures is indispensable before we can draw any conclusion. In the case of the excluded middle, this principle may seem more intuitively appealing to Westerners than to Easterners (see Nisbett (2003) for clues in this direction). To be sure that any cognitive mechanism is anywhere near universality, we should look for it in several very different cultures. Otherwise, we might be lured into thinking that the cultural development of some trait is the norm. Moreover, each culture can bring new clues as to the way cultural selection can tinker with our cognitive mechanisms, and, therefore, clues to those very mechanisms. The ideal case would be to study a culture, see it split into two sub-cultures that differ only for one trait, and test the influence of that difference on the cognitive mechanisms of the members of the two cultures. Obviously this cannot be done. Nonetheless, systematic studies of cultural variability will surely shed light on the influence of ecological or socio-economical traits of a culture on its members, but will also illuminate our understanding of universal cognitive mechanisms.

7. CONCLUSION

This chapter tried to show that we can use methods drawn from EP to explore some universal cognitive modules that are useful for mathematics. This point was illustrated with several modules, like the number sense which is now quite well defined within several fields (neurosciences, cognitive and developmental psychology, comparative studies). It then went on to explain how cultural evolution, pushed forward by the search of relevance in communication, can tinker with these modules. In this context the case of ancient Greece seems particularly important since it is the purported place of birth of formal logic and formal mathematics. A tentative explanation of this phenomenon is given using a broadly Sperberian framework and the findings of Richard Nisbett. If the ideas exposed are correct, they give some clues as to why mathematics is so effective in science. So this chapter uses ideas related to evolutionary epistemology since it postulates that phylogenetic evolution as endowed us with epistemic capabilities. It opens to language and culture in ways not often followed, by stressing the importance of cognitive mechanisms in cultural evolution.

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Computer modelling as a tool for understanding language evolution

Bart de Boer

AI Department, Rijksuniversiteit Groningen, Groningen, The Netherlands

Abstract

This paper describes the uses of computer models in studying the evolution of language. Language is a complex dynamic system that can be studied at the level of the individual and at the level of the population. Much of the dynamics of language evolution and language change occur because of the interaction of these two levels. It is argued that this interaction is too complicated to study with pen-and-paper analysis alone and that computer models, therefore, provide a useful tool for understanding language evolution. Different techniques are presented: direct optimization, genetic algorithms and agent-based models. Of each of these techniques, an example is briefly presented. Also, the importance of correctly measuring and presenting the results of computer simulations is stressed.

1. INTRODUCTION

People are fascinated by language, and love to talk and speculate about it. Whenever speakers of different languages or dialects get together, one of the favourite topics of conversation is the comparison between their different languages. Sooner or later, the origins of the differences and possibly the origins of language itself will be discussed. Scientists, not different from other people, like to speculate on the origins of language as well, and the field of language evolution has seen a renewed interest over recent years.

Different questions about the evolution of language can be investigated. When did language evolve? Which of our ancestors had language? Was it a relatively late invention, perhaps as late as 50,000 years ago when Homo sapiens apparently first started to make artistic and symbolic artefacts? Or was it much earlier and did Homo erectus, or perhaps even the Australopithecines already have language? A related question is how fast language has evolved. And *how* language did language evolve? Which evolutionary pressures played a role, and what factors determined that humans ended up with language,

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while other animals did not? Apart from historical events and circumstances, there are more general processes that determined the evolution of language. These can also be investigated. How much of language evolution is the result of purely biological evolution, and how much of it is cultural? What other factors, besides biological evolution of individual humans can have played a role? What was the role of co-evolution between language and the brain? And what was the role of co-evolution between infants' learning abilities and parenting behaviour? What is the role of self-organization, a process often encountered in complex dynamic systems? All these questions have indeed been investigated by different researchers (see e.g., Hurford, et al., 1998; Knight et al., 2000; Wray, 2002).

Evolution of language is also important for researchers interested in evolutionary epistemology. Evolutionary epistemology is here considered from a broad perspective as evolution of all human knowledge. Language, of course is a prime example of human knowledge. The interplay of different evolutionary factors is very visible in language. It is partly the result of biological evolution. Even if one does not like to postulate too many innate adaptations for language, it is clear that language has evolved under biological constraints of production and perception, for example. Language is also partly the result of cultural evolution. Languages change constantly over time, and there are important relations between being part of an ethnic/cultural group and the language that is used. The evolution of language can be used as a concrete example of how knowledge can evolve. Another perspective is to look at what evolutionary advantages can be conveyed with the ability to learn and use language. Finally, a third perspective from which language is interesting for evolutionary epistemology is that of the transfer of knowledge. A lot of knowledge is transferred through language, or at least greatly facilitated through the use of language. This must have an influence on how knowledge can evolve. Although the example of chimpanzee culture shows us that transfer of knowledge is possible in a pre-linguistic species, the presence of language must cause differences in the amount, the nature and the quality of knowledge that can be transferred.

Apart from being an undoubtedly interesting topic, language evolution is also a hard topic to investigate. Language is a complex phenomenon, and evolution is a complex phenomenon, so their relation is by necessity also very complicated. The evolution of human language is also in part the evolution of the human brain. Again, this is a very complex organ, and investigating its evolution is correspondingly complex. Then there is the interaction between human culture, its evolution and the evolution of language. Finally, evolution is a historical process. This means that it has been influenced by coincidences of human history and environment. Unfortunately, our knowledge of the history of human evolution is far from complete, and language itself does not leave any direct historical records, except in the case of written language. However, written language only goes back an insignificant amount of time when compared to the time over which language must have evolved. Therefore, physical evidence of the evolution of language is missing. Only some fossil hints about adaptation for speech exist (e.g., Kay et al., 1998; MacLarnon and Hewitt, 1999).

A problem that is both fascinating and hard invites speculation. And indeed, there has been no shortage of speculation about the origins of language. Unfortunately, most of this speculation has been wholly unscientific. For this reason, the Société de Linguistique de Paris in 1866 explicitly forbade all speculation on the origins of language. Still, Jespersen published a book on (among other things) the origins of language in 1922 (Jespersen, 1922). In it, he found it necessary to debunk a number of then current theories on the origins of language. However, the alternative he proposed, that human language was derived from song, did not have any better scientific foundation. The problem with much of this speculation was and is that it is trying to find one simple factor that caused language to emerge in humans. However, as has been argued above, the process of language evolution is both complex and dependent on historical coincidences.

Can we do better today? Although the nature of the question has not changed, our knowledge pertinent to the evolution of language has increased enormously. In 1866, the idea of evolution was still very recent: Darwin had only published *On the Origin of Species* (Darwin, 1859) 7 years previously. The reality of evolution was still being hotly debated. At the same time, most of linguistics consisted of shoehorning grammars of exotic languages into the grammar of Latin. As for fossil or other physical evidence of language, archaeology and palaeontology were only just getting off the ground. The first Neanderthal finds had only been made public in 1858 (Schaaffhausen, 1858). Since then, enormous progress has been made in all fields relevant to the study of the evolution of language. Evolutionary theory has developed spectacularly since 1859. We now know about selection pressures, sexual selection, group selection, cultural evolution and many other factors. Because of advances in biochemistry, we also know about the molecular basis of heredity. Our increased knowledge of biology, and of the related field of ethology (the study of animal behaviour) has also helped to advance the understanding of the evolution of language. We now know about communication systems in other animals, and about the cognitive abilities of our nearest evolutionary relatives, the great apes. These advances in biology and ethology have gone hand in hand with advances in the understanding of the neural mechanisms that underlie behaviour. We have learnt which parts of the brain are responsible for language and cognition and which parts in apes' brains are analogous to these. This has made it possible to form hypotheses about the evolution of the brain. These hypotheses, as well as hypotheses about the evolution of the general anatomy and behaviour of humans can be tested objectively because of the paleontological and archaeological finds that have been made over the last century and a half. Although fossil evidence will never be abundant, we now have a much more accurate picture of human ancestors. Last but not least, our understanding of what language is and how it works has improved considerably since 1866. Much more is known about what the possibilities of human language are. Many more languages have been described, and these descriptions are nowadays made without reference to the grammar of Latin. Special cases of language have also been described. Pidgin and Creole languages, especially, have shed light on the way new languages can be formed by populations of speakers. With our more extensive knowledge of the possibilities of human language, we can make better theories about the specific human adaptations for language. This growth of our knowledge has made speculation about the origins and the evolution of language more informed and more scientific.

But it is not just the increase of background knowledge that has made it possible to make and test more scientific hypotheses of the origins and the evolution of language. In this paper it will be argued that the use of computer models also constitutes an advance in methodology. Computer models allow researchers to investigate the implications of more complicated hypotheses than would be possible with pen and paper alone. This paper will only discuss examples of the use of computer models for studying language and language evolution. However, it is possible to use the techniques and the examples discussed here to build models for investigating evolution of more general knowledge.

The background of computer modelling in the study of language evolution will be expanded in the next section. Sections 3 and 4 are more technical. In Section 3 basic techniques for building computer models of language evolution are presented, while in Chapter 4 these techniques are illustrated with a few examples. These sections are intended for readers who are interested in building their own simulations, and can be browsed through rapidly by less technical readers. Section 5 discusses the implications of the techniques presented in this paper, and presents some of the conclusions on language evolution that have been reached by computer modellers.

2. THE USE OF COMPUTER MODELLING

In order to understand the use of computer modelling in the study of the evolution of language, we need to understand that there are two levels to language: the level of the individual and the level of the population. These two levels interact and this is an important factor in what makes the dynamics of language in a population so complicated.

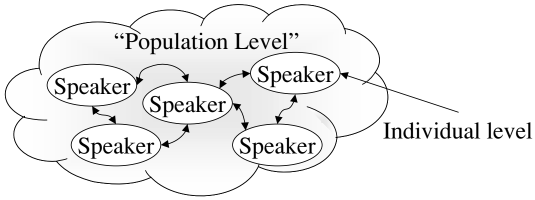

Figure 1. Language can be considered at both the individual level (the knowledge and performance of an individual) and the population level (the linguistic conventions in a population). There are feedback loops between individual's language and language conventions of the population, making the whole a complex dynamic system.

At the individual level, language is made up of individual speakers' knowledge of the language, of their limitations in production, of the speech errors they make, of the way in which they acquire language etcetera. This is the level that is related to what Chomsky has called *performance* (Chomsky, 1965) and what De Saussure has called *parole* (De Saussure, 1987). It is studied by psycholinguists who study such things as reaction times in retrieving words and limitations on short-term memory, by researchers of speech errors and speech pathologies, by researchers using neuro-imaging techniques and by researchers of language acquisition. Language at this level is intricately related to the functioning of an individual brain. Also, the language produced by each individual is slightly different.

On the level of the population, language is a conventionalized communication system, with a vocabulary and a set of grammatical rules. The knowledge in the population is uniform to such an extent that users of the language can communicate meanings and intentions with it. This is the level that is related to what Chomsky's *competence*[1] and De Saussure's *langue*. It is often assumed that the language at the level of the population is uniform over space and time. It is also often considered as an abstract system that exists in a sense separately from the individual speakers. Language at the population level is studied in historical linguistics and in general linguistics and is also what is described and prescribed by language teachers.

Both perspectives are equally valid when studying language. It would be impossible to reconstruct the history of a language if one had to take into account the behaviour of every individual. It would also be impossible to study organization of language in the brain without looking at the behaviour of individuals. However, it is obvious that these two levels do not and cannot exist separately. This is illustrated in Figure 1. The population level is an

[1] Chomsky views competence as individual knowledge, but I have the impression that it reflects idealized knowledge of linguistic conventions in the population. Therefore it is related to the population level and to De Saussure's langue.

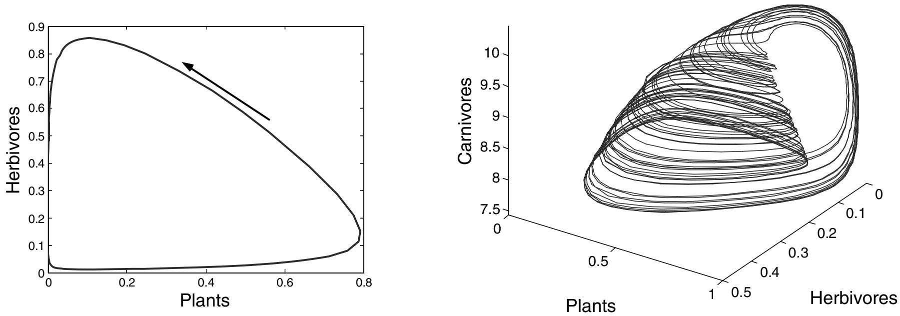

Figure 2. Example of predator-prey dynamics in an ecological model. The equations describing the system are Lotka-Volterra equations, and have been adapted from (Hastings and Powell, 1991). The left plot shows the dynamics of an ecosystem containing plants and herbivores. Such an ecosystem shows cylic behavior. The right plot shows the dynamics of the ecosystem if a carnivorous predator species is added. Suddenly and surprisingly, the dynamics become chaotic. Such phenomena would be almost impossible to investigate without computer models.

abstraction of the collective behaviour of a group of individuals. Behaviour on the individual level is influenced by what individuals perceive of the language used in the population of which they are part. The interaction between these two levels is a feedback loop. Changes in behaviour of an individual can change the collective behaviour and this in turn can influence the behaviour of individuals.

These feedback loops are by no means simple. The way language is learnt and the way innovations spread through a population are complex processes. Such systems cannot be described in a mathematically simple way. In a technical mathematical sense they are non-linear systems. As has already been observed by Steels (1998) language is a complex (non-linear) dynamic system. The behaviour of such systems is not easy to predict or even to describe. If one makes hypotheses about such systems, they will be extremely hard to test using pen and paper alone. An example of complex behaviour is illustrated in Figure 2. In this figure the behaviour of two ecosystems is compared. When the system goes from two species to three species, the dynamics become surprisingly more complex.

This is where computer models come to the rescue. Once described in sufficient detail, complex dynamic systems can be implemented as computer models. Computers can then simulate the behaviour of these models, and provide insights in how they work. When one compares the behaviour of the computer model with behaviour of the real system, one can check whether the predictions of the theory correspond to what is found in reality or not. Without computer models it would be extremely hard even to check what the exact predictions of the theory are. A common misunderstanding about computer models is that they only produce what has been put in beforehand,

and that they are, therefore, unable to produce any really surprising results. A complex dynamic system's behaviour is so difficult to predict that the results of simulating it are often very surprising.

Another advantage of using computer models is that one can use them to do what-if experiments. When studying language evolution or other large and difficult to control problems, it is often impossible to do controlled experiments. It is possible to observe the behaviour of the system under study, but it is not possible to change the initial conditions and see what happens or to restart the system to see what has happened in an earlier phase. Sometimes natural experiments happen, such as when a pidgin or Creole language is formed, but there are always many factors that one does not control. With a computer model, however, one has complete control over all parameters and even over the exact dynamics. One can also run and rerun the model as often as one wants. Computer models, therefore, make it possible to do as many hypothetical experiments as one wants.

In many fields of science, computer models are indispensable tools for investigating natural systems. One such field is meteorology, and more specifically climate modelling. The earth's atmosphere and its oceans also form a complex dynamical system that would be impossible to understand without computer models. Computer modelling allows us to investigate the long-term dynamics of this system and to perform hypothetical experiments on it by changing parameters and investigating how they influence the model's behaviour.

Using computer models to investigate aspects of complex biological systems has since 1989 been the domain of the field of artificial life (Langton, 1989). In this field, mainly biological models are tested using computer simulations. These models can be about behaviour of ecosystems (as in the example above) but also about the growth of plants (Prusinkiewicz and LindenMayer, 1990) or on such things as flocking in birds (Reynolds, 1987) or the emergence of ant trails (Colorni et al., 1991). From the beginning, artificial life researchers have been interested in using computer models to understand communication, but it wasn't until 1996 when the first conference on the evolution of language was held in Edinburgh, that the application of computer models to the evolution of language got a real boost. Since then the number of papers on computer modelling of language evolution has increased enormously.

Understanding how computer models are made and understanding how to interpret the results from computer models requires understanding of how an abstract system, such as a computer model, and reality map onto each other. Because computer power is limited, and because our understanding of language is limited as well, building a computer model requires us to make abstractions and simplifications. This is not a problem. Simplifications and abstractions are necessary for any scientific theory. Finding the right simplifications is also the key to making successful models of other complex phenomena, such as the example of the climate as we mentioned above. However, we should remain aware of the kind of simplifications we make. It is very important not too simplify a model too much, and thus to remove all interesting dynamics. This sometimes happens in systems that are designed for mathematical analysis. Mathematical analysis can only be done on the simplest possible models, and the kinds of models we are interested in are generally not solvable analytically.

Another possible pitfall is to compensate for necessary simplifications in one part of the model by making another part of the model more complicated. Often this only serves to obfuscate the behaviour of the system. It is important when modelling a particular problem, to analyse where the simplification bottlenecks of the model are, and not add unneeded complexity elsewhere. We can then build a model that is as simple as necessary and avoids complexity that does not contribute to the realism of the model. Investigation of speech can serve as an example: building a computer model with a very realistic speech synthesizer is not useful if it does not have a correspondingly realistic model of perception. In building and describing a computer model, it is very important to make our assumptions and abstractions explicit.

When interpreting and presenting results from computer models, we should be aware of how the results of the computer model map onto the linguistic phenomenon under study. For a model of speech sounds this mapping is usually quite straightforward. Such models generally work with direct representations of physical properties of the speech sounds under study. For models of more abstract properties of language, this mapping can be quite intricate. Semantics (meaning) can serve as an example. Meanings in computer models are often implemented as simple numbers that are a measure of how strong the association between a word and an object in the world is. This is easy to implement, but a rather strong simplification of the complexities of semantics in human language. Such more abstract representations require an effort from the author to present the results of the model and from the reader to interpret them. It is, therefore, essential to clearly communicate the mapping between objects in the computer model and real linguistic entities and to explain how the results of a computer model shed light onto the real linguistic phenomena.

One should also be very careful not to use computer models to investigate aspects of language that they have not been designed for. For example, one can build a computer model for investigating certain properties of speech sounds that does not have a realistic language acquisition component. It would then be disastrous to use this model for investigating language acquisition. Although this is a very obvious example, assumptions and abstractions in a computer model can be extremely subtle. It is easy to forget the exact nature of these assumptions, and the problem gets worse when a computer model that one researcher has designed is used by other researchers.

Deciding which abstractions and simplifications to use is one step in making a computer model Another step is which computational techniques to use for the computer model. Sometimes the problem one is interested in and the simplifications one has made already determine which techniques can be used. Like the abstractions and simplifications, all different techniques have their advantages and disadvantages.

3. COMPUTER MODELLING TECHNIQUES

There are many different techniques that are suitable for modelling the evolution of language. Most of these techniques can be divided in three categories: optimization techniques, genetic algorithms and agent-based models. Optimization techniques define a quality measure on (linguistic) systems and try to optimize it. Genetic algorithms are techniques inspired by biological evolution that try to evolve a good linguistic system using a population of candidate solutions. Agent-based models model (a population of) language users as simplified computer programs, and try to emulate how they use language. These categories provide a framework for presenting the different techniques, but it should be kept in mind that they are somewhat arbitrary. There are finer distinctions that can be made within the categories and the boundaries between categories are not always clear.

3.1. Optimization

The hypothesis underlying optimization as a computer modelling technique is that many linguistic structures are in a sense optimized. Different optimization criteria are postulated for different aspects of language. For speech sounds they could be acoustic distinctiveness and articulatory ease. For grammatical constructions, they could be learnability and parsability. For semantic distinctions and categories, learnability and coverage of the semantic domain could play a role. Cross-linguistic observations and psycholinguistic studies have indeed shown that languages appear to be optimized, at least to a considerable extent. This is relevant in two ways for the study of the evolution of language with computer models. It can be investigated for which factors human language really is optimized, and how the process of optimization is brought about in human language. Optimization criteria can be investigated by generating artificial linguistic systems using different optimization criteria and comparing these systems with real human linguistic systems. If there are important similarities, it is likely that the optimization criterion also plays a role in human language. If the systems are not similar, the criterion probably is not relevant. The second perspective on optimization in language looks at the different ways in which linguistic structures have become optimized. This can have happened through for example biological evolution or cultural evolution. Usually, either genetic algorithms or agent-based models are used for this kind of research, so we will focus on the first kind only in this section.

The basics of implementing optimization are relatively straightforward. A computer model is used to find the linguistic system with the highest quality for some property. Three things are needed for an optimization model. First, a representation of the linguistic system under study is needed. This can be a set of speech sounds, a grammatical system or a vocabulary of words with different meanings. I is crucial that these representations can be modified in small steps in order to optimize them. Second, a quality measure is needed that determines how good a given linguistic system is for the task one wants to investigate. It is advisable to use a function that is easy to calculate and that is smooth. Ease of calculation is important if one wants to make efficient computer models. Smoothness for a quality function is defined as the property that a function gives similar values for similar inputs. In the case of linguistic systems this means that similar systems will have similar quality values. This is important, because most optimization techniques do not work well with quality functions that are not smooth. The third element of an optimizing model is the optimization algorithm. Both the representation of the linguistic system and the quality function depend on the problem one wishes to investigate. Most optimization algorithms, however, are task-independent.

Optimization algorithms generally work by keeping track of the best solution found so far, by making small modifications to this solution and by replacing the old best solution whenever a new solution with higher quality is found. The main differences between different optimization algorithms are in the way new candidate solutions are generated. If very little is known about the behaviour of the quality function, the only possibility is often to randomly explore the neighbourhood of the best solution found so far. If one knows that the quality function is smooth, one can use a technique called hill climbing, in which one tries to follow the steepest path up the quality function. A particularly robust optimization technique is simulated annealing (Kirkpatrick et al., 1983). Here one explores random solutions in the neighbourhood of the best solution found so far. Over time, one shrinks the size of the neighbourhood in which new solutions are searched. This causes the algorithm to locate the approximate solutions of peaks in the quality function first, and subsequently climb up a promising peak. Both hill-climbing and simulated annealing are illustrated in Figure 3.

It is important to note that, except for the simplest possible problems and quality functions, optimization does not always find the best solution. This

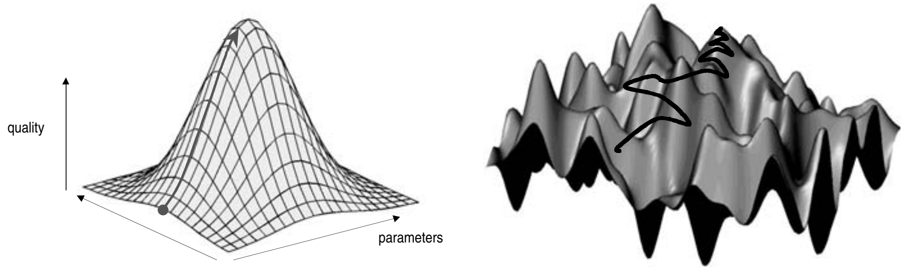

Figure 3. Two different ways of optimizing a quality function. On the left the *hill-climbing* algorithm is shown. It climbs up a peak in the quality function using the steepest ascent. On the right simulated annealing is illustrated. It uses ever decreasing random steps to find the best solution. Note that hill-climbing would most likely get stuck on a sub-optimal peak in this complex landscape.

problem is illustrated in Figure 3, where the simulated annealing procedure does not find the highest peak. Straightforward optimization is, therefore, not recommended when one wants to find the *best* possible solution to a problem. This is however, not usually the case in linguistic problems. Human languages show a fair degree of variation for most if not all properties, even though they are usually close to optimal. An algorithm that manages to find near-optimal solutions most of the time is, therefore, usually good enough.

Optimization is probably the technique that is least controversial in its applications, as its dynamics are relatively simple: there is an optimization criterion and it results in linguistic systems that are similar to human systems or not. Discussion is possible about the implementation and representation of the linguistic structure, about the quality function that was used, or about the interpretation of the structures that are found, but the optimization process itself is not controversial. The simplicity of optimization is also a disadvantage. It can only be applied to relatively simple problems. As soon as multiple optimization criteria interact, the optimization process becomes more difficult and decisions have to be made about which solutions to investigate. However, optimization is a good technique for checking which criteria play a role in human languages. How these criteria have become important and how the optimization process takes place in human populations must be investigated with different techniques.

3.2. Genetic Algorithms

The second paradigm is that of genetic algorithms (GA's). The genetic algorithm (e.g., Goldberg, 1998) is a technique that is based on the way evolution works in nature. Instead of keeping track of only one potential solution, the algorithm has a *population* of potential solutions. Just as in optimization, it has to be decided how these solutions are represented in the computer model. However, in a genetic algorithm there are two levels of representation: the level at which solutions are evaluated (which is similar to the representation in optimization) and the level in which solutions are recombined and mutated by the genetic algorithm. This is analogous to the distinction in biology between the phenotype (the grown individual) and the genotype (the individual's genes). Analogous to this, solutions in a genetic algorithm must be representable in terms of artificial genes. In most implementation of genetic algorithms, simple bit strings are used for representing genes. When needed, these genes are converted into possible solutions to the problem at hand (linguistic structures in the case of models of language). These solutions can then be evaluated with a fitness function. This fitness function is comparable to the quality function in optimization. It is a function that gives a high value for good solutions and a low value for bad solutions.

Just as in nature, solutions with a high fitness are allowed to create offspring, while bad solutions are removed from the population. When solutions with high fitness are selected, their genes are used to create new genes for offspring that will replace the bad solutions that have been removed from the population. The idea is that in this way, genes coding for high quality solutions will multiply in the population, while genes coding for bad solutions will disappear.

In order to create offspring based on the parent solutions, combination methods inspired by nature are used. The most important operator is direct copying: most of the time, offspring must be very similar to their parents. Another important operator is mutation. Mutation causes genes in offspring to be different from parent genes. When working with bit strings, mutation generally consists of flipping one of the bits in a gene. Mutation should not be done too often otherwise solutions tend to deteriorate. Another important operator is crossover. In crossover, genes from two parents are combined to form offspring. With this operator one hopes to combine good properties from both parents but it is equally possible that one would combine bad qualities.

However, in this case, the resulting low-quality offspring will not be selected for transfer to subsequent generations. Both mutation and crossover are illustrated in Figure 4. As in optimization, the right fitness function and the right coding of are essential for the proper functioning of a genetic algorithm.

Many different variants of genetic algorithms exist. There are differences in the exact implementation of the genes and the genetic operators. Often it is important to tailor them to the problem that one wants to solve. Other differences exist in the way one can handle simultaneous optimization of different criteria. The classical GA only optimizes one criterion, expressed in the fitness function. It is of course possible to combine multiple criteria in one fitness function, but as a GA works with a population of solutions, it is also possible to keep all solutions that are the best in each of the

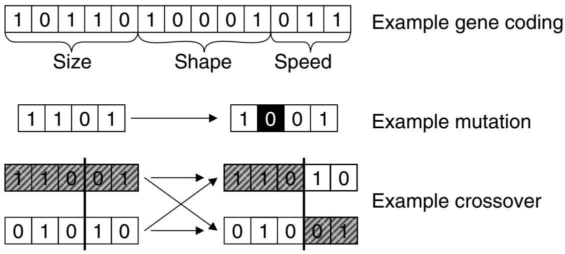

Figure 4. Examples of coding of solutions in terms of genes (for example the size, shape and speed of an animal) and of mutation and crossover operators for generating new genes.

criteria one wishes to optimize. This procedure is called pareto-optimization. Making an effort to keep multiple different solutions is in general a good strategy when using genetic algorithms. Because of the selection process, diversity tends to disappear from the population over time if nothing is done to preserve it. Diversity preserving schemes generally select individuals for procreation by taking into account fitness and how different the individual is from the other individuals with high fitness. If it is very similar, the probability that it will be chosen is diminished. If it is different, the probability will be increased.

GA's are similar to straightforward optimization in that they also optimize on the basis of an optimization criterion (the fitness function), but they are much more flexible and robust. Part of their strength lays in the fact that they keep track of multiple potential solutions. They can, therefore, be used to model more complex optimization problems and even problems in which the optimization criterion changes over time. Also, the fact that GA's work with a population of solutions makes them more realistic in the case of language. Language is typically used in a group of individuals rather than by a single individual. Finally, genetic algorithms are modelled after (neo-) Darwinian evolution, and are as such ideally suited for modelling real evolution.

Their resemblance to real biological evolution is possibly the biggest advantage of genetic algorithms when used for research into the evolution of speech. But modellers who enthusiastically embrace genetic algorithms as their paradigm of choice should be aware that there are a large number of design decisions to be made in building a GA for investigating the evolution of speech. Decisions have to be made what to encode as genes and how to implement the fitness function. Another very important point is that one should not confuse biological evolution of the human faculty for speech and cultural evolution of human languages. Historical relations between languages and historical change of languages are often expressed in terms similar to those of biological evolution. It is true that there are definite and valid similarities between the processes of biological evolution and language change, but one should not confuse the two processes in one's model. They are clearly distinct and operate on totally different time scales. They do influence each other, but this influence happens because the properties of a learned system (the language) influence the fitness of individuals that have to learn it. This is an interesting subject of investigation in itself, and it is called the Baldwin effect (Baldwin, 1896).

Summarizing, genetic algorithms are a powerful means of optimizing complex systems. This requires selecting an appropriate fitness function and an appropriate representation, both of the linguistic structures that are investigated, as well as their representation as artificial genes. GA's can also be used to study the mechanisms and dynamics of biological and cultural evolution. However, some care must be taken, both by researchers and by readers of papers in which GA's are used, not to confuse these two aspects.

3.3. Agent-Based Models

Both direct optimization and genetic algorithms assume that there is a property of linguistic systems that can be optimized. This can give interesting results, but it is not always the case that one can identify one easy criterion that is optimized in human linguistic systems. Also, optimization techniques ignore the fact that humans are not optimizers. When humans acquire or use a language, they do not optimize it. They try to conform to the linguistic behaviour that they observe. This is an example of the feedback between the individual's use of a language and the use of it in a population. Apparently, over time this results in optimization of many properties of language, but how this optimization emerges remains to be explained.

This is where agent-based models find their use. In computer science, agents are small computer programs that can act and interact independently in some limited domain. They are able to perceive aspects of their environment and are able to act on it. This environment is usually simulated, although there are agents that act in non-simulated environments. These are, for example, agents that can act on the Internet, agents that can interact with human computer users in a user interface, or even robotic agents that can act in the real world. Often the environment of an agent contains other agents with which it needs to interact. In linguistic agent-based models, individual language users are modelled. These individuals are capable of some limited linguistic feats, depending on what they are used for. Agents that are used for investigating speech sounds are able to perceive produce and learn speech sounds. Agents that are used for investigating syntax are able to produce, parse and learn syntactically structured utterances. For each linguistic question, specialized agents can be designed. The agents then interact in some way, usually by exchanging linguistic utterances, by observing their (shared) environment and

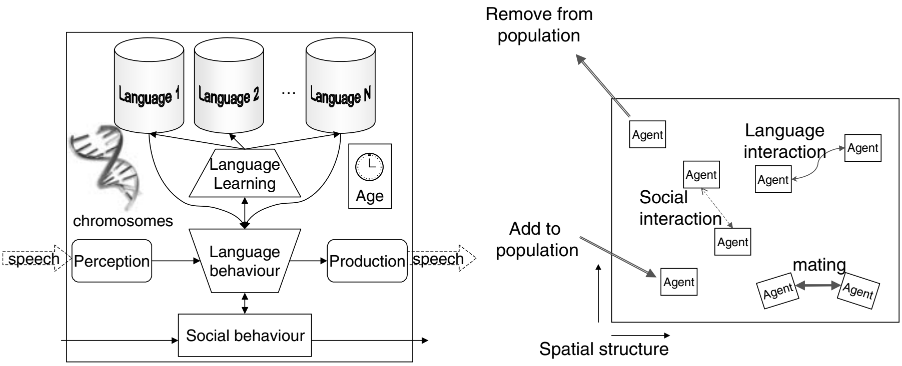

Figure 5. Components of an individual agent (on the left) and possible population dynamics (on the right).

by observing the non-linguistic behaviour of other agents. Depending on the interactions, the agents can modify their linguistic knowledge. The influence of the individual actions and interactions on the linguistic systems can then be investigated.

There are more design decisions that need to be taken when constructing an agent-based model than when constructing an optimizing algorithm or a genetic algorithm. Apart from the representation of the linguistic data, decisions have to be made about how the agents interact and how they react to the interactions. On the interaction side, decisions must be taken about what aspects of human interaction must be modelled. Will there be an age structure in the population of agents? Will there be a social structure? Will there be a spatial structure, such that agents that are far apart are less likely to interact than those that are close? Will agents only exchange linguistic information, or will there be non-linguistic interaction as well? Will agents be able to mate with each other and produce offspring? Some of the possible interactions in a population of agents are illustrated in Figure 5.

There are also many design decisions that need to be made when constructing individual agents. First of all, it needs to be decided what linguistic utterances these agents can produce and perceive. This is of course determined by what linguistic questions one wants to investigate. These questions also determine what linguistic knowledge must be stored and how it can be learned. It needs to be decided as well whether an agent will be able to learn only one language, or whether it will be able to learn multiple languages. Part of an agent's implementation is determined by the interactions it performs. Furthermore, it should be decided how and if agents change when they become older and how they react to social status. Finally, if an agent-based model is combined with a genetic algorithm, so that agents can produce offspring, it needs to be decided what genes the agent has and how it will mate with other agents. Although agent-based models can become extremely complicated, they are usually kept relatively simple. Making them too complex would result in behaviour that is difficult to describe and interpret.

There are two dominant paradigms in agent-based modelling. One paradigm has been introduced by Steels (1995, 1997, 1998) and is called the language-game approach. The other paradigm has been introduced by Hurford and Kirby and is called the iterated learning model (e.g., Kirby, 1999). Both paradigms can be used for investigating any aspect of language. In the language game paradigm, large populations of agents are investigated. These agents are typically egalitarian: there is no distinction between adults and children, or between social classes of agents. It is also typical in this paradigm that agents start out without any linguistic knowledge, and that they 'negotiate' a language between themselves. Language games are typically used for investigating cultural or 'horizontal' transmission. In the iterated learning paradigm, agents are typically divided in adults and infants. Adult agents produce linguistic utterances, but do not learn, while infant agents learn, but do not produce utterances themselves. At regular intervals, adult agents are removed from the population, infants are turned into adults and new, empty infants are inserted. Populations are also typically small, often as small as one infant and one adult agent. Iterated learning models are typically used for investigating how languages change when they are transmitted from one generation to the next, and which types of language are stable under such 'vertical' transmission.

Although much has been said (Kirby, 2002; Steels, 2002) about the differences between the two paradigms, they are really two extremes on the continuum of possible agent-based models. If one considers the space of possible agent based models that vary over both the number of agents in a model and the ratio between the number of horizontal transmissions (within a generation) and the number of vertical transmissions (across the generations) one finds that typical language games are in the corner where there number of agents is large and there are horizontal transmissions exclusively, while typical iterated learning models are in the corner where the number of agents is low and there are vertical transmissions exclusively. Between these two extremes, other agent-based models are entirely possible, and have in fact been investigated.

3.4. Measures and Statistics

Computer models, and especially genetic algorithms and agent-based models generate a lot of data. In a simple model for investigating vowel systems (de Boer, 2000) there were 20 agents, each with up to ten vowels that each had three parameters. Such a model requires 600 parameters for its description, and this for every time step. Models that are used for investigating more complex aspects of language generally have many more parameters. As simulations are run for tens of thousands of time steps, the amount of data generated by a complete run is immense. A human observer cannot interpret such amounts of data. It is, therefore, necessary to define *measures* on the model that give a reliable indication of its performance. These measures serve as summaries of the model's behaviour over time.

It is tempting to choose the optimization criterion used in an optimizing model or the fitness function in a genetic algorithms as the measures. However, this would be wrong. By definition, these values will be optimized. Although the way in which this happens might be interesting in itself (how long does it take, does it continue to change, or does it go to an asymptote etc.) other measures must be monitored in order to learn something about the linguistic aspects of the model.

For clarity of description, it is important that measures are easily understandable by linguists and other non-modellers. At the same time they must give useful information about the way the modelled linguistic system changes over time. Examples of such measures are: average distinctiveness of sounds in a sound system, number of elements in a linguistic system, success of communication between different agents or coherence of the linguistic systems of different agents in a population. Although some measures are more general than others (size of the linguistic system, or coherence in the population are very generally applicable for example) special measures of performance need to be defined for each model.

When these measures have been defined, it becomes necessary to gather statistically significant information about a model's behaviour. As in many models randomness plays an important role, this needs to be modelled using the computer's pseudo random number generator. A simulation can then be run many times with different initial values for the random number generator. In this way, a distribution of the different possible outcomes of the model can be generated. Two things must be taken into account in this procedure. First of all, it must be ensured that a proper random generator is used. Some standard random generators are of low quality. Secondly, the kinds of distributions that emerge from simulations of linguistic phenomena are not often normally distributed. One should, therefore, be careful to apply the correct statistical analysis procedures.

4. EXAMPLES

In order to illustrate some of the concepts discussed above, three examples of computer models of language origins will be presented below. Each of these examples illustrates one of the three basic techniques: optimization, genetic algorithms and agent-based models. In order to aid the comparison, all of them model sound systems.

4.1. Optimization: The Liljencrants and Lindblom Model

One of the first computer models aimed to investigate factors in the origins of human language was made by Liljencrants and Lindblom (1972). This model was intended to investigate whether the universal tendencies of human vowel systems can be explained as a result of optimization of acoustic distinctiveness. It had been found by linguists that the vowel systems of human languages show a number of regularities: some vowels occur more often than others, and some combinations also occur more often than others. Liljencrants and Lindblom suspected that these regularities could be explained by maximization of acoustic distinctiveness between all the vowels in a language's vowel repertoire. It was not possible to test this hypothesis analytically, so it was decided to use a computer model.

In this model, vowels were represented as points in an acoustic space. In order for the results to be relevant to linguistic, this space and the representation of the vowels in it had to be perceptually realistic. Phoneticians usually describe the acoustic properties vowels using the first and second (and sometimes third) *formant*. Formants are the resonance frequencies of the vocal tract, and most vowels are distinguished by the lowest two resonances. When represented in a perceptually correct frequency scale (the Mel frequency scale, for example) distances between vowels in the space of the first and the second formant correspond to perceptual distances. Liljencrants and Lindblom, therefore, decided to represent the vowels in their model by their first and second formants. As humans are not able to articulate every possible combination of two formants, the space in which vowels could occur was restricted to a roughly triangular area. The vowel space is illustrated in Figure 6.

In this acoustic space, a variable number of vowels can exist. In order to calculate optimal distinctiveness, Liljencrants and Lindblom consider them as magnets that repel each other. The strength of the force with which they repel each other is inversely proportional with the square of the distance. In this way, the system has potential energy. This potential energy is calculated with the following formula:

$$E = \sum_{i=1}^{N} \sum_{j=1}^{i} \frac{1}{d_{ij}^2}$$

where E is the energy, N is the number of vowels and d_{ij} is the distance between vowels i and j. Both the representation of vowels as points in a two-dimensional space, and the quality of a vowel system as the potential energy in

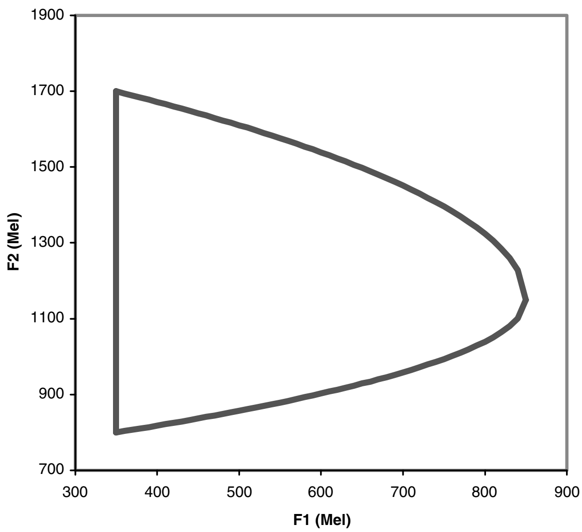

Figure 6. The acoustic space used by Liljencrants and Lindblom (1972). Note that the two dimensions used are the first (F1) and second (F2) formant. Frequencies are in Mel instead of Hertz. Vowels are only allowed within the red area.

a group of repelling magnets are important simplifications that are, however, linguistically acceptable.

Just as repelling magnets strive towards a situation with minimal potential energy, vowel systems can be minimized for potential energy. This is done by initializing the vowels to lie on a small circle in the centre of the acoustic space. Then each vowel in turn is moved away from this circle in order to decrease the potential energy. The optimization procedure tries to shift the vowel in six different fixed directions over a 100 Mel distance. It keeps the new position that results in the largest decrease in potential energy. When it is no longer possible to move a given vowel away so that potential energy decreases, the next vowel on the circle is tried. This process is repeated until no more reduction in potential energy can be achieved. This particular optimization procedure is an instance of *hill climbing*. For more details, the reader is referred to the original paper.

Liljencrants and Lindblom compare the systems that emerge from their optimization procedure with vowel systems that are found in human language, and find that their model results in realistic vowel systems, especially for smaller numbers of vowels (up to six). The measure they use is the number of vowels that is different between their optimized vowel systems and real human vowel systems, but because of the considerable variation in human vowel systems, this comparison is a bit impressionistic. As the representation of vowel systems in their optimization model is so close to the way linguists represent vowels, the mapping between their results and real vowel systems was straightforward.

4.2. Genetic Algorithms: The Redford Model

As has been explained in Section 3, optimization models work well when a single criterion needs to be optimized and when the optimization function is relatively smooth. When a problem does not have these properties, a genetic algorithm works better. Syllable systems, as tackled by Redford et al. (1998, 2001) have too many complex properties for straightforward optimization, and were, therefore, modelled with a genetic algorithm.

Redford et al. wanted to investigate how properties of human syllable systems can be explained as the result of constraints on perception and production. They also wanted to know what the relevant constraints are. In their model, languages are modelled as collections of words. These words have only form, no meaning. Initially, words consist of random combinations of a small number of phonemes (i, a, u, p, t, k, s, l, n). Phonemes all have a number of binary features, such that distances between them, and, therefore, between words, can be calculated. The facts that meaning is not modelled and that words are represented as strings of units are important abstractions in this model.

There are a number of perceptual and articulatory pressures on the language. First of all, no two words can be identical. Because of ease of articulation, short words are preferred. Also because of ease of articulation, simple consonant clusters are preferred over complex consonant clusters. Word initial consonants are preferred over word final consonants. Because of acoustic distinctiveness, words should be as different from each other as possible. Finally, because humans produce words by rhythmically opening and closing their jaws (Redford et al. call this the mandibular oscillation constraint) adjacent phonemes must differ as much as possible in jaw opening. These different pressures conflict. Preference for short words, for example, is in conflict with maximal distinctiveness. In different runs of their model, Redford et al. tested different combinations of constraints to check which ones are needed to produce the most human-like syllable systems.

Words were the units of selection. As words already consisted of strings of discrete units, they did not need to be separately coded as genes. Crossover and mutation were performed directly on the words themselves. In order to assign fitness to words in the population, vocabularies consisting of 25 words were randomly selected from the whole population. For each of these vocabularies fitness was calculated. The fitness of a word was then set to the average of the fitness of all vocabularies in which it occurred. This is a somewhat non-standard way of assigning fitness, but Redford et al. use it in order to determine the distinctiveness of words in the language. In a sense, this is a way of preserving diversity, as has been discussed in the description of genetic algorithms. The fittest words were then selected and allowed to create a new language using crossover and mutation.

Redford et al. compare the syllable systems that emerge with syllable systems found in human languages and draw the conclusion that the constraints that they have investigated are sufficient to explain human syllable systems, and that it is perhaps not necessary to include both the mandibular oscillation constraint and the constraint against consonant clusters. When operating without the other, both these constraints result in realistic syllable systems. On independent linguistic evidence (infant babbling) they conclude that it is probably the mandibular oscillation constraint that is the one that operates in reality.

4.3. Agent-Based Models: The de Boer Model

The last example that will be discussed is that of an agent-based model that has been investigated by the author himself (de Boer, 1997, 2000, 2001; de Boer and Vogt, 1999). It is in a sense a continuation of the work by Liljencrants and Lindblom (1972). They provided an explanation of why vowel systems are the way they are: they are optimized for acoustic distinctiveness between the different vowels in the repertoire. However, their model does not provide an explanation of *how* these systems have become optimized. Humans do not explicitly optimize the vowel systems they learn. The hypothesis that was tested with the agent-based model was that the optimization is the result of self-organization under constraints of perception and production in a population of language users.

The model most closely resembles Steels' language game paradigm (Steels, 1997) in that no generations of agents are modelled, but that horizontal interactions (interactions between agents in the same generation) are modelled. It consists of a population of agents that can each produce and perceive vowels in a human-like way. For this purpose they are equipped with a simple vowel synthesizer and a model of perception that, like in the Liljencrants and Lindblom model, is based on formants. Perception of vowels is categorical: an acoustic signal is perceived as the nearest category in an agent's repertoire. Agents are also able to learn new vowels and to modify vowels in their repertoire based on the interactions they have with other agents.

These interactions are so-called imitation games. The goal of the imitation game is to imitate the other agents as well as possible. Imitation was selected as a simplification of real linguistic interactions, as no notion of meaning is required, but the same functional pressures as occur in real language are involved. In an imitation game, two agents that have been randomly selected from the population interact. One agent selects a vowel from its repertoire, and the other agent tries to imitate it, using the vowels in its own repertoire. As the repertoires can be different, it is possible that the imitation this agent produces sounds quite different from the vowel that was originally produced. If the first agent hears the imitated vowel as the same vowel it originally produced, the imitation game is successful, if not, it is a failure. Depending on the outcome of the imitation game, the participating agents update their repertoire, such that the expected success of subsequent imitation games is increased. In these updates they can only make use of local information: they cannot look into other agents' heads, nor can they do global optimization of their own vowel system. For details on the agents and the imitation games, see (de Boer, 1999, 2000, 2001).

Agents start out empty, and develop a repertoire of vowels through repeated interactions. As the agents live in a population, part of the challenge is to develop a repertoire that is shared throughout the population. Experiments with the model have shown that shared vowel systems emerge rapidly and reliably in the population. When these systems were compared with human vowel systems, it was found that they are extremely similar. An example of an emerged five-vowel system is shown in Figure 7.

Different measures were used to determine the performance of the model. One measure was the Liljencrants and Lindblom energy of the emerged vowel systems. This was shown to be significantly lower than that of randomly generated vowel systems and close to the energy of explicitly optimized vowel

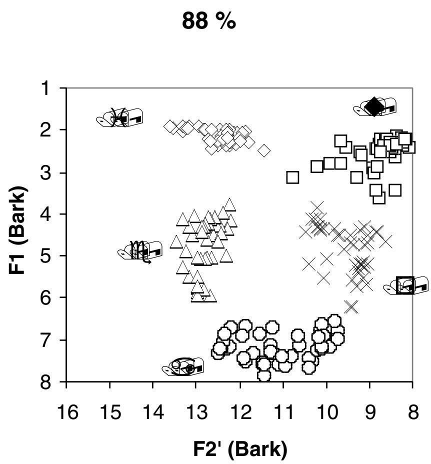

Figure 7. Example of emerged five vowel systems. The vowels are plotted in the space of the first (F1) and second (F2) formants, in the logarithmic Bark frequency scale. Five-vowel systems that emerged from 33 different simulation runs are plotted. It can be observed that the vowel systems for each simulation run are very similar, and that they are very close to the vowel system consisting of /i/, /e/, /a/, /o/ and /u/, the vowel system that occurs most frequently in human languages. This particular five-vowel system occurs in 88% of languages that have five vowels.

systems. This indicates that optimization is an emergent property of the interactions in the population. Another measure was the imitation success of the emerged vowel systems, which was shown to be universally high. This is an indication that the emerged vowel systems were successful for imitation. A final measure was the size of the emerged vowel systems, which tended to be as large as possible given the amount of noise that was put on the articulations. This too indicates emergence of successful vowel systems. Given that the imitation game uses categorical perception, it would have been trivial to achieve successful imitation with small vowel systems. Finally, vowel systems were compared directly with human vowel systems. This was done in a somewhat impressionistic way by comparing the emerged configurations of vowels with the configurations that are found in human languages, and by checking whether the emerged vowel systems showed the same universal tendencies as those found in human languages. From both comparisons, it followed that the emerged vowel systems were realistic.

On the basis of this simulation, a number of variants have been tried. These had mostly to do with adding age structure to the agents, and with removing old and adding new (empty) agents to the population (de Boer and Vogt, 1999). These modifications added vertical transmission to the original model, thus making it resemble the iterated learning model. It was shown that vowel systems could remain stable in changing populations, and that making it harder for old agents to learn increases stability of the vowel systems. This example illustrates that once an agent-based model exists, it is very easy to expand it to do other experiments.

5. CONCLUSION

Computer models are a useful addition to studying the evolution of language. They can provide insight in the factors that have played and still play a role in making language the way it is, and they can simulate the complex dynamics of language in a population. Neither pen-and-paper analysis nor mathematical analysis can so readily help us to understand such complex phenomena. Many different hypotheses on different aspects of language have been studied successfully with a range of techniques. The examples given above only provide a small taste of what has been done in the case of the sound systems of human language. For overviews of computational models for all aspects of language, see for example (Cangelosi and Parisi, 2002; Kirby, 2002; Christiansen and Kirby, 2003). Most of these models have shown that cultural interactions, functional pressures and general learning mechanisms can explain a lot more about language and language evolution than was previously assumed.

As language is a form of knowledge, evolution of language can be considered from the viewpoint of evolutionary epistemology. The implications for the study of the evolution of knowledge are that it is indeed possible to explain properties of certain types of knowledge as the result of evolutionary mechanisms. As has been shown, these mechanisms can be both cultural and biological. Computer models can be extended to investigate other aspects of the evolution of knowledge. So far, the influence of the use of language on the fitness of agents has not been investigated in much detail (but see De Jong, 1999 for example). Apart from linguistic knowledge, other forms of knowledge are also still an open field of research. That interesting research can be done with computer models is shown by Belpaeme and Steels (Steels and Belpaeme, 2005) who have investigated colour from an evolutionary perspective.

In the preceding sections, it has been shown that there are three different basic techniques for building computer models of human language: optimizing models, genetic algorithms and agent-based models. In some cases these techniques can be combined, for example when agent-based models are combined with a genetic algorithm to model agent evolution. As has been illustrated in the examples, these different techniques can all be applied successfully, depending on what it is exactly one wants to investigate. In building simulations, it also needs to be decided what simplifications and abstractions to make. This is the real art of modelling and useful and meaningful simplifications can make the difference between a usable and an unusable computer model. Finding the right simplifications takes a lot of creativity and effort. Another important aspect of modelling is finding the right measures to describe the performance of a model. Designing the right measures takes creativity as well, but fortunately, measures can often be reused for different simulations.

Of course we should not get carried away by our enthusiasm for computer models. Computer models are just an extra tool in understanding language evolution. We should be careful to combine computer modelling with careful analysis of the available data and with knowledge and understanding of the available linguistic data. We should take care not to end up investigating the computer model itself, instead of using it for understanding linguistic questions, unless, of course, one is interested in the mathematical aspects of the model. Also, we should be careful not to use a computer model for understanding phenomena that it was not intended to model. This is especially a risk when using computer models that have been developed by others. For example, the agent-based vowel model described above cannot be used for investigating realistic language change, as real language change is influenced by the phonetic context in which sounds occur, as well as the meaning of the words in which they are used. Both aspects are missing in the model.

In any case, it is necessary that we carefully state the assumptions and abstractions that were made when constructing the computer model. The ways in which the results of the computer model map back onto real linguistic phenomena also need to be described. This is especially necessary, because many researchers of language evolution are still quite sceptical about the use of computer models. Partly this scepticism is justified, as sometimes too bold claims are made, but a large part of the scepticism is unwarranted and due to a lack of understanding and appreciation of the way computer models work.

There is still a lot that can be done with computer models. A number of open problems remain, even though they have received ample attention from different researchers. The problem of how combinatorial syntax can emerge from non-combinatorial systems has not been understood completely. Neither has the emergence of combinatorial sound systems from holistic utterances. Together these problems would provide insight into the duality of patterning that is so characteristic for human language. Another example of an open problem is the co-evolution of the shape of the vocal tract and the increasing number of distinctions that need to be made for more complex languages. These problems lay at the edge of the understanding of language evolution, and the use of computer models is a promising way of solving these fascinating problems.

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Simulating the syntax and semantics of linguistic constructions about time

Joachim De Beule

Artificial Intelligence Lab, Vrije Universiteit Brussel, Brussels, Belgium
joachim@arti.vub.ac.be

Abstract

In this paper we motivate and report on the implementation of a computer experiment to investigate the syntax and semantics of linguistic constructions about time. It is argued that the way in which a domain like time is conceptualized is not universal and evolves over time. To investigate this we want to simulate a population of agents evolving their proper language and ontology of time in order to succeed in communicating temporal information. Such simulations can be done using a formalism proposed by Steels (2004). Some advances in applying the formalism to the domain of time are reported and examples of actual simulations are presented.

1. INTRODUCTION

In this paper we motivate and report on the implementation of a computer experiment to investigate the syntax and semantics of linguistic constructions about time. It is argued that the way in which a conceptual domain, like time, is structured and conceptualized by humans is not fixed but differs from culture to culture and evolves over time. This is especially true for the semantics of linguistic constructions since language is a conventional system, and the meaning of, for example, a grammatical tense category is conventionally determined (Lapolla, n.d.).

A language is not an isolated system of word to meaning mappings and grammar rules that can be used to express things about the world in some universal way. A language cannot exist outside the context of an environment inhabited and shaped by a population of language users. When a member of a language community wants to engage in a communicative interaction he has to conform to the consensus in that community, both in the way he conceptualizes the topic that he wants to express as in the way he verbalizes the conceptualization. A child hearing a new word or grammatical construction has to

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hypothesize about what is intended and how the word or construction should be used. She will have succeeded when she herself is able to use the construction successfully. In other words, when she finds that the other members of her language community seem to correctly understand the hypothesized meaning or communicative intent expressed by the new construction as she uses it. It is possible however that she does not use the construction as was intended, that she uses it in a novel but successful way, or even that she uses a construction that wasn't even there (grammaticalization), but still is successful in using it. At this point the new conceptualization or rule she introduced might become part of the language and she is herself constructing the language that she is trying to learn.

Hence, to study language we need to look at it as an evolutionary and self-organizing system in which language users try to figure out their environment (to *survive* in it) by learning the language but in the mean time constantly shaping and creating that environment themselves. Moreover, both the meaning and form of a language are subject to this evolution. There is no universal way to conceptualize the world for language. Rather, conceptualization schemes should be valued by their usefulness in communication. As Nathalie Gontier (this volume) explained, looking at language in this way and studying it from this perspective means implementing evolutionary epistemology in the field.

2. THE ARTIFICIAL INTELLIGENCE APPROACH

In artificial intelligence (AI) we try to build computational or robotic systems that act and interact in some intelligent way. One way to study cultural evolution and phenomena like language is to put together a population of such systems and see what it takes for them to evolve a language. In this case it is common to call an individual system or instance thereof an *agent* and a population or group of interacting agents a *multi-agent system*. Thus an agent is a robot or program representing an individual and in a multi-agent simulation a population of such agents interacts with each other and with the environment.

To study language as an evolutionary system we simulate a population of interacting agents with the goal of letting them evolve their proper language. This way we can gain insight in both what capacities and mechanisms an individual agent needs to accomplish this goal and in the structure and evolution of language as a cultural phenomenon. It should be clear however that these two levels cannot exist separately: the evolution of an individual agent both depends on and determines the evolution of the language and vice versa.

The ultimate goal is to find out how a population of agents can establish a set of conventions about the expression of temporal information. For this to be possible, the agents have to agree upon an ontology in the domain of time. By an ontology we mean a set of categories or distinctions with which an agent can conceptualize the world.

As is explained in Steels (1998), the emergence of a *shared* set of categories requires the interaction among the members of the population and a co-evolutionary coupling between the categories that make up the ontology and the forms to express them. Thus, an agent should be capable of doing at least three things. First, he should be capable of creating new categories. Second, he should be capable of incorporating these categories into his language repertoire. Third, he should be capable of adapting his language and ontology in order to conform to the (emerging) consensus in the population.

In another paper (De Beule, 2004) a mechanism is proposed to accomplish the first prerequisite: the creation of new temporal categories by playing a generalized discrimination game. In short, when an agent has to conceptualize a topic event he builds a description for it. A description could for example state that the topic is a walk event. Such a description is considered adequate if it uniquely describes the topic with respect to the other events in the context. If the agent is unable to build such a description the creation of a new category is triggered. For example if the topic event is a walk event in the past, but also another walk event is taking place in the present, a new distinction or category distinguishing present from past events is created. The description of the topic can now be extended by specifying that it is the walk event in the past. The creation of a new category and the subsequent adoption of the category into the agent's ontology (category repertoire) is called a discrimination game.

The current paper focuses on how the resulting temporal categories can be incorporated into an agent's language repertoire using a formalism proposed by Steels (2004).

The third step, the interaction between the different agents and the resulting co-evolution of meaning and form is not discussed in depth (although see Section 5.2 for some first results.) Still, the underlying assumption is that every act of communication attempts to guide the interpretation process of a hearer to arrive at the topic. Consequently, a new conceptual category or syntactic extension to the language should only be introduced when it will help the interpretation process. This allowed Steels to postulate a mechanism by which a speaker can decide when to extend the syntax of the emerging language: he first listens to himself and interprets his utterance as if he were a hearer. As such he can detect and solve ambiguities before actually pronouncing an utterance. This mechanism and the language formalism have been successfully used to simulate the emergence of a case grammar (Steels, 2004). In this paper we will apply it to the domain of time.

3. INVESTIGATING LANGUAGE AS AN EVOLVING CONVENTIONAL SYSTEM

3.1. Motivation

One of the primal aspects of language is that it is used for communication. If the communication is to be successful, the users of the language need to agree upon both what to express and how to express it. Both of these are partly predetermined by the world and the physiology of the agents. But they are also partly conventional and optimized to make them more efficient for the purpose of communication.

For example there exist only a finite set of vowel systems used in human language. As was shown by De Boer (2001), each such system is a trade-off between its expressive power and its understandability given the constraints of human physiology, of the physics of air as transmission medium etc.

The set of categories and relations that are made explicit in a language is partly conventional as well. For example, the distribution of colors in the world and the properties of the human visual system only partly explain the way in which color is categorized for language. Each particular color categorization scheme is also the emergent result of a negotiation between the members of a language community (Belpaeme, 2001).

Similar observations can be made in the domain of time. There are many commonalities between the ways in which time is conceptualized across different cultures. Most if not all cultures conceptualize time as progressively and irreversibly moving forward from the past to the future on a linear time line (Comrie, 1985). Time is a deictic system so a reference is needed to specify a location in time. In probably all languages the current moment or moment of speech is used for this. Most cultures also have notions for today, yesterday, etc. (although Hopi might be an exception, see Whorf (1956) or Yee, (n.d.a, n.d.b) for a discussion on Whorf's claims about the Hopi concept of time.) Because of the nature of time and its importance to daily life it is no surprise to find these commonalities.

Still, there are indications that the categorization of time is not universal but also in part cultural or conventional. For example, if we move from daily life to a more philosophic or religious domain, some cultures clearly have concepts of time that are cyclic. As another example, the more technically advanced a culture is the more elaborate and precise the temporal categorization becomes.

In addition there is great variety in the way in which temporal information is encoded in different languages. If it is true that form and meaning co-evolve to adapt to the need for efficient communication there should also be some variety in the way time is conceptualized. In the following we will show that there *is* great diversity in expressing temporal information across different languages and even within one language.

3.2. Diversity in the Expression of Temporal Information

First, not all languages express similar information in the same way. For example, almost all cultures make metaphorical associations between the future and the front of the body. This convention is used extensively while making gestures accompanying an utterance. It can also be observed in words like 'be-fore' where the 'fore' part means in front. There are however cultures that associate the *past* with the front of the body and accordingly express temporal information with opposite gestures and different metaphors (Nunez, 1999).

Second, not all languages require the same temporal information to be made explicit. For example in Chinese there is no tense system and temporal information is specified lexically or with aspectual categories. Chinese has a relative aspectual system, e.g. in the sentence:

kui sik joh faan siin jau

he eat ASP dinner then leave

the aspectual marker marks completion of dinner relative to leaving. But it is not specified whether this happens in the past, present or future so there are still different interpretations possible:

(1) He ate dinner, then left.
(2) He always eats dinner before leaving.
(3) He will eat dinner, then leave.

These have to be disambiguated by the conversational context or by providing extra information (Yee, n.d.a, n.d.b).

In contrast with this, in Bantu languages it is common to have *several* tense categories for different degrees of remoteness in time, e.g. making a distinction between *a few days ago* and *more then a few days ago* (Comrie, 1985).

Even among the members of the same language community there can be differences in the meaning associated with a temporal category. An example from Dutch is the meaning of the future tense form. The future tense is constructed by combing the verb *gaan* (to go) with the infinitive. In standard Dutch '*ik ga eten*' means '*I will eat*', placing the eat event in the future without any additional connotation. In many Belgian dialects however this construction means '*I will eat* here and now'. This is in opposition with the construction '*ik ga gaan eten*'. This construction is not grammatical according to standard Dutch but is very widely used. The meaning of *'Ik ga gaan eten'* is more or less captured by the sentence '*I will go and eat/with the purpose of eating*'. There seems to be an additional meaning of displacement putting the eat event in the more distant future. This construction is not limited to eating but can be made with practically all verbs, i.e. *'Ik ga gaan zwemmen'* (I will go and swim). An exception might be the verb gaan (to go) itself: it is normally not acceptable to say '*ik ga gaan gaan'* although some people consider even this grammatical.

This diversity can be explained by the fact that language is a complex dynamic phenomenon and the emergent global result of local peer-to-peer negotiations. New members entering a language community might trigger changes in the meanings and forms of the language. For example, the origin of the English future tense form (will + infinitive) is closely related with that of the still separately existing verb *'willen'* (to want) in Dutch. Wanting something is closely related with the future and in English *'will'* became used to indicate the future tense.

Hence, one way to gain insight into language is to build systems evolving their proper language. This has been done in a variety of ways (e.g. De Jong, 2000; Kirby, 2001; Steels and Kaplan, 2002). In the rest of the paper we will report on some advances in building such an experimental setup to investigate the conceptualization and expression of temporal information.

4. FORMALISM AND MECHANISM

As explained, the aim is to simulate a population of agents evolving a shared ontology and language. The force that drives the evolution is the *desire* of the agents to be successful in communication. While trying to accomplish this goal the agents are forced to invent new categories and extend the language. In Steels (2004) a formalism for construction grammars and accompanying learning strategies are presented that are specifically designed to do such simulations. In the following two sections we will summarize this formalism and illustrate the mechanism by which new rules are introduced by an agent. We refer to Steels (2004) for details.

4.1. Formalism

The agents in our experiments need a way to represent semantic and syntactic information. This is done with feature/value structures called units. A unit also has a name. A collection of units is called a unit structure or simply structure. An example of a semantic structure is shown in Figure 1.[1]

[1] Predicates and variables are written in *italics*, variables also with a capital first letter. The value of a unit's meaning feature is a predicate calculus like logical expression possibly containing variables.

unit-1

meaning: {*fall(X)*}

Figure 1. A semantic structure containing one unit named unit-1 and containing one feature named meaning. Meanings are represented in standard predicate calculus-style, i.e. the value of the meaning feature is *fall(X)*.

Semantic structures specify constraints on the meaning to be expressed or interpreted (interpreting a semantic structure means finding bindings for all the variables in the meaning to things in the world). Every semantic structure is mirrored by a syntactic structure containing units with the same names as those in the semantic structure. Syntactic structures contain constraints on the form to be expressed or interpreted.

Agents also need a way to represent lexicon entries and other rules of language. This is done by specifying a transformation between unit structures. A rule normally contains a semantic pole and a syntactic pole. The application of a rule in production is done by first matching the semantic pole against a semantic structure to get a set of bindings and then (if a match is found) unifying the syntactic pole with the corresponding syntactic structure. In interpretation the matching is done against the syntactic structure and the semantic pole is unified with the corresponding semantic structure. An example of a lexical rule is given in Figure 2. It specifies that the part of the meaning that is equal to *fall(X) & past(X)* is expressed by the word ‘fallpast’ and vice versa. The formalism is thus closely related with construction grammar and cognitive grammar formalisms.

4.2. Mechanism

Imagine an agent placed before a screen where movies of falling and rolling objects are shown. Assume he gets to see a fall event followed by a roll event

rule fall-past

Unit

meaning:+ {*fall(X) & past(X)*}

<–>

Unit

form:+ {stem(‘fallpast’)}

Figure 2. A lexical rule associating the word ‘fallpast’ with the meaning *fall(X) & past(X)*. A rule is printed as follows: first the left pole (a unit structure containing variables) followed by an arrow (<->) followed by the right pole. The ‘:+’ means that the feature value ‘should at least contain’ the specified elements.

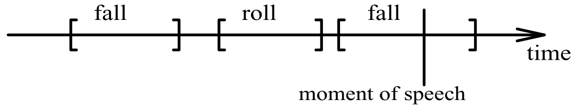

Figure 3. A fall event followed by a roll event followed by a fall event.

followed by another fall event. The second fall event is still taking place at the moment that he wants to draw another agent's attention to the past fall event (see Figure 3).

First, he has to build a semantic structure describing the event, for example stating that it is a fall event as is shown in Figure 1. However, this description is not specific enough to discriminate the topic from the other fall event in the context. The addition of a temporal category could solve this problem. Assuming that the agent's set of temporal categories is still empty the agent can decide to create a category *past.* Such a discriminating category can be found by playing a (generalized) discrimination game as is explained in De Beule (2004). Adding the category *past* to the semantic structure in Figure 1 results in the semantic structure shown in Figure 4.

Next, the agent has to identify applicable lexical rules by matching their semantic pole against this semantic structure. When a matching rule is found, the unification of its syntactic pole with the syntactic structure will result in the addition of syntactic (lexical) information specifying the form. For clarity, in this section the semantic and syntactic structures will be shown as one structure containing both meaning and form features. It is possible that (part of) the meaning is uncovered by the lexicon. In this case new lexical rules have to be introduced. There are several possibilities. If the entire meaning is uncovered one word is associated with it. For example associating the word 'fallpast' with the structure shown in Figure 4 results in the rule shown in Figure 2.

If, however, the agent's lexicon already contains an entry for *fall* he only has to introduce a rule associating a new word with the *past* part of the meaning. New units are introduced if the meaning of a unit is broken down in the lexicon into more than one word. Thus, the application of two separate lexical entries for *fall* and *past* transform the structure of Figure 4 into the one shown in Figure 5. The syntactic information in this structure can be used to assemble

unit-1
    meaning: {*fall(X) & past(X)*}

Figure 4. The semantic structure of Figure 1 extended with a temporal category *past*.

unit-1
subunits: {fall-unit, past-unit}
fall-unit
meaning: {*fall(X)*}
form: {stem('fall')}
past-unit
meaning: {past*(X)*}
form: {stem('did')}

Figure 5. The result of applying lexical rules for 'fall' and 'past' to the semantic structure of Figure 4.

the utterance. The result is either 'fall did' or 'did fall' (there is no word order defined).

Now assume a hearer knowing the word 'fall' receives this utterance. He has to figure out two things: (1) the meaning of the word 'did' and (2) the fact that both words 'fall' and 'did' are about the same thing.

To solve problem (1) the hearer should in some way be able to deduce that the topic is the past fall event, e.g. by joint attention or by the speaker pointing to it. But even if this succeeds the hearer might still make a different conceptualization for the topic, for example stating that it is the fall event *before the roll event*, thereby mistakenly associating the meaning *before(X,Y) & roll(Y)* with the word 'did'. Such an error will become apparent in future interactions and cause the adaptation of the agent's ontology and/or lexicon.

To solve problem (2) some additional syntactic constraints on the utterance should be added reflecting the constraints at the semantic side. The fact that the variables in the fall-unit and the past-unit are the same (the variables to the *fall* and the *past* predicates in Figure 5 are both *X*) can be considered as a constraint at the semantic level. This constraint should also be specified in some way at the syntactic level. This is comparable with the lexical rule in Figure 2 which connects a constraint on the form feature of a unit to contain the word 'fallpast' (syntactic level) with a constraint on the meaning feature to contain the meaning *fall(X) & past(X)* (semantic level).

To express the equality of the variables in both units another syntactic constraint is needed, for example word order. The agents could postulate a rule stating that if the word 'did' directly precedes the word 'fall' it can be concluded that the corresponding meanings are about the same thing. This is accomplished with the rule shown in Figure 6. This rule introduces word

```
rule fall+past
    Parent-unit
        subunits:+ {Subunit-1, Subunit-2}
    Subunit-1
        meaning:+ {fall(X)}
    Subunit-2
        meaning:+ {past(X)}
<->
    Parent-unit
        subunits:+ {Subunit-1, Subunit-2}
        form:+ {precedes(Subunit-1, Subunit-2)}
    Subunit-1
        form:+ {stem('fall')}
    Subunit-2
        form:+ {stem('did')}
```

Figure 6. Example grammatical rule introducing word order.

order as can be seen by the *precedes* constraint in the syntactic pole of the rule. Hence, this is a first step toward a language with non-trivial syntax. The mechanism responsible for this step is the introduction of syntactic constraints on the form (e.g. word order) reflecting semantic constraints on the meaning (e.g. the equality of variables in different units).

The rule in Figure 6 is not general but only applies to the specific combination of *fall* and *past*. A way to arrive at a more general rule is to introduce semantic and syntactic categories.[2] For example, if *fall(X)* would be of category *semcat1(X)*, 'fall' of *syncat1, past(X)* of s*emcat2(X)* and 'did' of category *syncat2*, the rule in Figure 7 would achieve the same result as the fall+past rule of Figure 6. But this rule is more general because it can be applied to any combination of units having the correct semantic and syntactic categories. It is still not very clear however how to determine the members of a particular semantic or syntactic category. Some very promising results are reported in Steels (2004) where the re-use of categories is driven by analogy.

[2] These categories are not to be confused with ontological categories like *past*. A semantic category (like object, event, agent ...) is a categorization of a conceptual relation used to constrain the semantic pole of grammatical rules. A syntactic category (like verb, noun, nominative ...) is a categorization of a word or group of words used to constrain the syntactic pole of a grammatical rule.

```
rule cat1+cat2
    Parent-unit
        subunits:+ {Subunit-1, Subunit-2}
    Subunit-1
        semantic-category:+ {semcat1(X)}
    Subunit-2
        semantic-category:+ {semcat2(X)}
  <->
    Parent-unit
        subunits:+ {Subunit-1, Subunit-2}
        form:+ {precedes(Subunit-1, Subunit-2)}
    Subunit-1
        syntactic-category:+ {syncat1}
    Subunit-2
        syntactic-category:+ {syncat2}
```

Figure 7. A more general version of the rule shown in Figure 6 using semantic and syntactic categories.

To summarize, new lexical rules are introduced by a speaker when the lexicon does not cover the entire meaning that is to be expressed. To detect opportunities to introduce new grammatical rules the speaker can interpret his utterance as if he were a hearer. Some of the constraints present in the semantic structure of the production phase will not be present in the semantic structure of the interpretation phase. For example, an equality of two variables might be missing. He can then add grammatical rules to solve this problem.

5. SOME SIMULATIONS AND RESULTS

5.1. Simulating One Agent

In this section the details of some actual simulations are shown in which an agent acts as a speaker and looks for opportunities to add new rules. The world presented to the agent is shown in Figure 3, with the past fall event called fall-1 and the present fall event fall-2. In other words, the context that is presented to the agent is given by the conjunction *fall(*fall-1*) & roll(*roll*) & fall(*fall-2). The agent is also aware of every event's begin and end time and

unit-1
Referent: fall-1
Meaning:
{ *end*(fall-1)
< *end*(fall-2)
& *fall*(fall-1)
& *fall* (fall-2) }

(a)

unit-1
Referent: fall-1
Meaning:
{ beg*in*(fall-1)
< *end*(roll)
& *fall*(fall-1)
& *roll* (roll) }

(b)

unit-1
Referent: fall-1
Meaning:
{*end*(fall-1)
< *begin*(now)
& *fall* (fall-1)
& *now* (now) }

(c)

Figure 8. Three different conceptualizations observed in simulations for conceptualizing the past fall event in the context of Figure 3.

of the current moment. His goal is to produce an utterance describing the past fall event.

5.1.1. Conceptualization

In all examples the agent starts with conceptualizing the topic by building the semantic structure shown in Figure 1, but with the variable X instantiated as (replaced by) fall-1. Because this semantic structure is not specific enough to uniquely describe the topic (also the present fall event is described by the semantic structure) the agent adds a temporal category. In Figure 8 three possible solutions are shown that were observed during different simulations.

The first conceptualization (Figure 8a) describes the topic as the fall event which ends before the end of the fall-2 event. The second conceptualization (Figure 8b) describes the topic as the fall event that begins before the end of the roll event. The third (Figure 8c) describes it as the fall event that ends before the current moment (*now*). All conceptualizations uniquely describe the fall-1 event within the context of Figure 3. In the following we will continue with the semantic structure given by Figure 8c.

5.1.2. Application of lexical rules

After successfully conceptualizing the topic and constructing a semantic structure the agent looks for matching lexical rules. As explained in Section 4.2, the particular combination of lexical rules applied also determines how the semantic (and syntactic) structure is decomposed. If part of the meaning is uncovered by the lexicon new lexical rules are invented. On the left, the result is shown for an agent with an empty lexicon. The agent created a new rule (Figure 9a) covering the entire meaning of the structure in Figure 8c. Applying this rule to the structure results in the structure of Figure 9b. On the right, the result is shown for an agent who already had a rule associating the *fall*(fall-1) part of the meaning with the word ‘zapaxo’. He created a new rule associating the remaining part with the word ‘fovuxi’ (Figure 9c). These rules transform the structure of Figure 8c into the one of Figure 9d.

```
rule zivatu
   Unit
      referent: X
      meaning:+ {fall(X) & now(Y)
                   & end(X)<begin(Y) }
<->
   Unit
      form:+ {stem('zivatu')}
```

(a)

```
rule zapaxo
   Unit
      referent: X
      meaning:+ {fall(X)}
<->
   Unit
      form:+ {stem('zapaxo')}
rule fovuxi
   Unit
      referent: X
      meaning:+ {now(Y)
                   & end(X)<begin(Y) }
<->
   Unit
      form:+ {stem('fovuxi')}
```

(c)

```
unit-1
   referent: fall-1
   meaning: { end(fall-1)<begin(now)
              & fall(fall-1)
              & now(now)}
   form:{ stem('zivatu') }
```

(b)

```
unit-1
    subunints: {unit-2, unit-3}
unit-2
   referent: fall-1
   meaning: {fall(fall-1)}
   form: { stem('zapaxo') }
unit-3
   referent: fall-1
   meaning: { end(fall-1)<begin(now)
              & now(now)}
   form: { stem('fovuxi') }
```

(d)

Figure 9. Two different lexical rule sets and unit structures resulting from applying the rules to the structure shown in Figure 8c. In the simulation the rules are created by the agents as they need them to cover the meaning in the structure.

5.1.3. Creation and application of pre-grammatical rule

We will continue the example with the unit structure shown in Figure 9d. Before uttering the phrase specified by this structure the agent listens to himself to determine ambiguities. The phrase specified by the unit of Figure 9d is 'zapaxo fovuxi' or 'fovuxi zapaxo' (there is no word order specified).

Translating the utterance 'zapaxo fovuxi' back into a unit structure using the lexical rules of Figure 9c results in the structure shown in Figure 10. As can be seen, the main difference with the structure of Figure 9d is that now variables are introduced. In addition, the variable for the *fall* predicate in unit-5 is X-1, while the variable that should be bound to fall-1 in unit-6 is X-2. Interpreting this structure within the context of Figure 3 means finding bindings for the variables X-1, X-2 and Y such that all meaning parts in the structure become true. The *now(Y)* part of the meaning feature in unit-6 specifies that the variable Y should be bound to the current moment. The other variables X-1 and X-2 should be bound to one of the events fall-1, fall-2 or roll. Since it is not

```
unit-4
     subunits: {unit-5, unit-6}
     form: precedes(unit-5,unit-6)
unit-5
    referent: X-1
    meaning: {fall(X-1)}
    form: { stem('zapaxo') }
unit-6
    referent: X-2
    meaning: { end(X-2)<begin(Y)
                   & now(Y) }
    form: { stem('fovuxi') }
```

Figure 10. The unit structure resulting from interpreting the utterance 'zapaxo fovuxi' using the lexical rules shown in Figure 9c.

specified that X-1 and X-2 should be equal there are several solutions: X-1 can be bound to both fall-1 and fall-2 and X-2 can be bound to both fall-1 and to roll. To solve this, the agent should add an extra constraint on the form of the utterance, for example specifying word order or introducing case. In the specific simulation being discussed the agent introduced the 5 rules shown in Figure 11a to 11e. These specify that

(a) the word 'zapaxo' is of syntactic category syncat-1 (rule syncat-1),
(b) the word 'fovuxi' is of syntactic category syncat-2 (rule syncat-2),
(c) the meaning *fall(X)* is of semantic category semcat-1 (rule semcat-1),
(d) the meaning *end(X) < begin(Y) & now(Y)* is of semantic category semcat-2 (rule semcat-2) and finally that
(e) if these categories are combined then the word of syncat-1 gets a suffix '-lo' and the word of syncat-2 gets a suffix '-ri'.

If the agent now re-verbalizes the semantic structure of Figure 8c by applying these rules to the semantic structure of Figure 9d the resulting utterance would be 'zapaxo-lo fovuxi-ri' or 'fovuxi-ri zapaxo-lo' (there is still no word order specified.) And in interpretation the rule of Figure 11d will specify that the variables X-1 and X-2 in Figure 10 have to be equal because they will both get bound to the same variable X of the rule (the variables in the values of the referent features of units *Subunit-1* and *Subunit-2* are both X.)

5.2. Simulating a Population of Interacting Agents

In the previous section we looked at the internals of a single agent. In this section we discuss a simulation of a population of 10 interacting agents. These agents are simplified with respect to the agents discussed in the previous section and results are therefore preliminary. The agents in this section are only allowed to use holistic lexical rules, i.e. lexical rules that cover the entire

```
rule syncat-1
  Unit
    form:+ {stem('zapaxo')}
->
  Unit
    syncat: syncat-1
```

(a)

```
rule syncat-2
  Unit
    form:+ {stem('fuvuxi')}
->
  Unit
    syncat: syncat-2
```

(b)

```
rule semcat-1
  Unit
    referent : (X)
    meaning:+ { fall(X) }
->
  Unit
    semcat: semcat-1
```

(c)

```
rule syncat-2
  Unit
    referent : (X)
    meaning:+ {end(X)<begin(Y)
               & now(Y)}
->
  Unit
    semcat: semcat-2
```

(d)

```
rule cat-1+cat2
  Parent-unit
    subunits:+  { Subunit-1, Subunit-2 }
  Subunit-1
    referent : (X)
    semcat   :  semcat-1
  Subunit-2
    referent : (X)
    semcat   :  semcat-2
<->
  Parent-unit
    subunits:+  { Subunit-1, Subunit-2 }
  Subunit-1
    syncat  :  syncat-1
    form    :+ {suffix('-lo')}
  Subunit-2
    syncat  :  syncat-2
    form    :+ {suffix('-ri')}
```

(e)

Figure 11. (pre-)grammatical rules introduced by the agent to make the variables *X-1* and *X-2* of the structure in Figure 10 equal, this way solving the multiple interpretation problem.

conceptualization as does for example the rule in Figure 9a. Consequently, the application of the lexicon does not fragment the unit structure. This means that no grammar rules like the rules of Figure 11 are used since they are not needed. Still some interesting results can be shown, for example that such a population is indeed capable to converge to a shared ontology and language to communicate temporal information. It will also be shown that, in this simulation, both the conceptualization and the syntax of language are, at least partly, conventional.

5.2.1. Setup of the experiment

The experiment consists of a number of successive two-agent interactions. Each interaction, two agents are randomly selected from the population. One of them is the speaker, the other the hearer. Both agents are presented with the same context, on average consisting of five events. The speaker randomly selects one of these events as the topic. Next he tries to conceptualize this event as was the case in the previous section, thereby using a temporal category from his category repertoire. If there is no category in his category repertoire that can be used to uniquely describe the topic, the agent creates a new temporal category for it, thereby extending his category repertoire (see also De Beule, 2004). It is also possible that several categories in the repertoire uniquely conceptualize the topic. In that case he chooses the category that was most successful in previous interactions. Next, the speaker searches his lexicon for entries that express the conceptualization. If no entry can be found, his lexicon is extended with a new entry associating the temporal category with a new word. If several entries are found, the one that was most successful in previous interactions is chosen. Finally, the speaker utters the word to the hearer who has to interpret it in the context, i.e. the hearer has to determine the event that the speaker chose as topic.

To do so, the hearer first determines the lexical entries that match the uttered word. It is possible that several entries match. Only those with an associated temporal category that uniquely determines one event in the current context are considered. In other words, only the *relevant* entries are considered. Of these, the entry that has been most successful in the past is chosen to determine the topic. If this event indeed is the speaker's topic, the interaction ends successfully. If not, the interaction ends unsuccessfully. It is also possible that there was no matching lexical entry. In this case also the interaction ends unsuccessfully. In the case of an unsuccessful interaction the speaker points to the intended topic so that the agents can adjust their language repertoires (categories and lexicon).

The precise details of the adjustment procedure are not discussed in this paper. The philosophy behind it is that an agent should try to mimic the majority of the other agents in the population. Every time an agent interacts with another agent he samples the population and gains information about the language repertoires of the other agents. This information can be used by the agent to adjust his own language repertoire. Information is gained by both the speaker and the hearer and in both successful and unsuccessful interactions. For example, note that even when an interaction ends successfully, this does not mean that both the speaker and the hearer used the same temporal category. Nor does it mean that the hearer would have used the same word to describe the topic since he could for example have conceptualized it differently. In this case, the adjustment procedure will encourage the hearer to use the speaker's

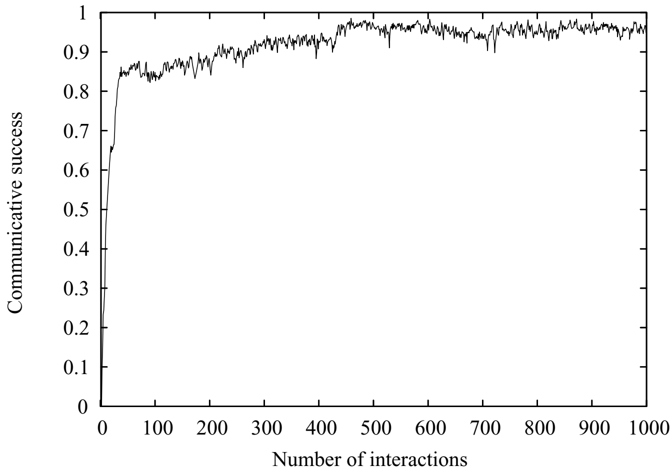

Figure 12. Evolution of the communicative success in time (number of interactions) in a population of 10 interacting agents (see text for details).

word in future interactions and discourages the use of the word that he himself would have used. In addition, when a word was unsuccessful too many times or when its use was discouraged too many times, it is removed from the agent's lexicon. The same holds for temporal categories.

5.2.2. Results

In Figure 12 the evolution of the communicative success among the agents in the population is shown. The communicative success is the probability of having a successful interaction between two randomly picked agents when presenting them with a random context.[3] One can see that communicative success increases fast in the beginning with the increase rate slowing down as time proceeds. After 10,000 interactions the communicative success reached 99.9% (not shown in Figure 12).

As was already explained, a successful interaction does not per se mean that both agents have the same category repertoire or lexicon. Similarly, a high communicative success does not mean that the population has converged to a small but shared set of temporal categories or words to express them.

It is also possible that although agents start to understand the words used by other agents, they would have used another word themselves. There is a high degree of synonymy of which most agents are aware (hence a high

[3] This context should of course be similar to the contexts shown to the agents during the experiment, in the current experiment for example containing on average 5 events.

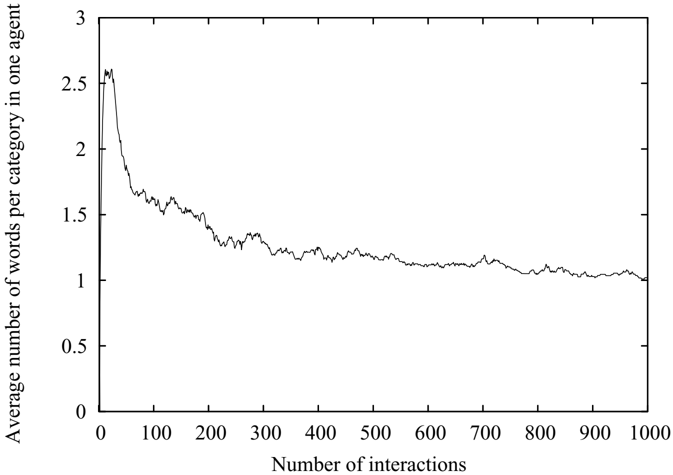

Figure 13. Evolution of the number of words associated with a temporal category averaged over all categories and all agents in the population.

communicative success), but no consensus about which word to prefer has been reached yet. This is indeed illustrated by Figure 13 which shows the average number of words associated with a single category in an agent (averaged over both agents and temporal categories).

As explained, the agents not only need to agree upon a lexicon, they also have to agree upon an ontology for time with which they can conceptualize the world. What is a useful set of temporal distinctions or categories to conceptualize the temporal aspects of the world is partly determined by the world itself. But there could be many useful sets of temporal categories compatible with the world. And in the case that the world or environment includes the population in which temporal information is to be expressed, usefulness is also partly conventional. Thus, we should also expect an increase in the similarity of category repertoires between different agents and in the average number of categories associated with a word as the agents are converging to a consensus. This is shown in Figures 14 and 15. Note that the category similarity does not reach 100%. Apparently, to reach almost complete communicative success it is not necessary for all category repertoires of all agents to be equal. This of course depends on the structure of the world and the kind of contexts the agents are presented with.

Finally, Figures 16 and 17 show that the average size of an agent's language repertoire (lexicon plus categories) does not simply increase (which would explain communicative success as it does in the first 50 interactions) but converges to a minimal but sufficient and (partly) conventional set of words and categories.

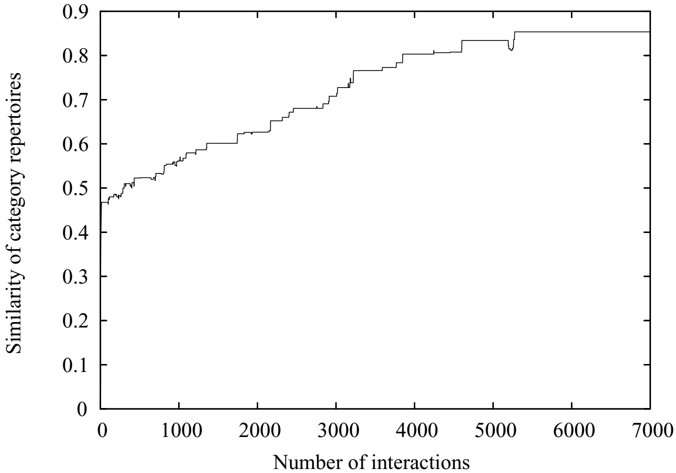

Figure 14. Evolution of the similarity between the repertoires of temporal categories of the different agents in the population, averaged over all pairs of agents. The similarity of two repertoires is 1 if both repertoires are of equal size (same number of categories) and contain the same categories. The similarity is zero if the two repertoires have no category in common.

The (primarily quantitative) differences between words and categories (compare for example Figures 13 and 15 or Figures 16 and 17) in these experiments can be explained by the fact that the temporal category repertoire that an agent adopts (by creating a new category when needed or removing one from its repertoire when unsuccessful etc.) is biased by the world (all

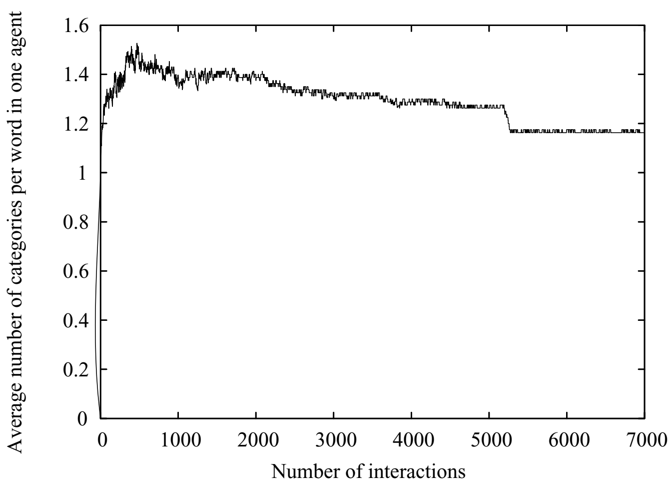

Figure 15. Evolution of the number of temporal categories associated with a word averaged over all words and all agents in the population.

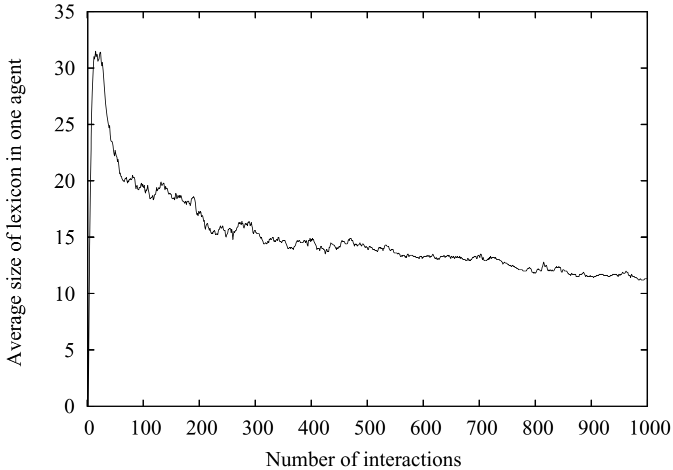

Figure 16. Evolution of the average size of an agent's lexicon (category/word associations).

agents experience the same world) and by the algorithm that creates new temporal categories. In contrast, the choice of which word to use for some conceptualization is purely conventional (new words are created in a random fashion.) Still, part of the resulting temporal category repertoires is clearly conventional as well since the repertoires of different agents become smaller and more similar as time passes and agents are adjusting to conform to the emerging consensus in the population.

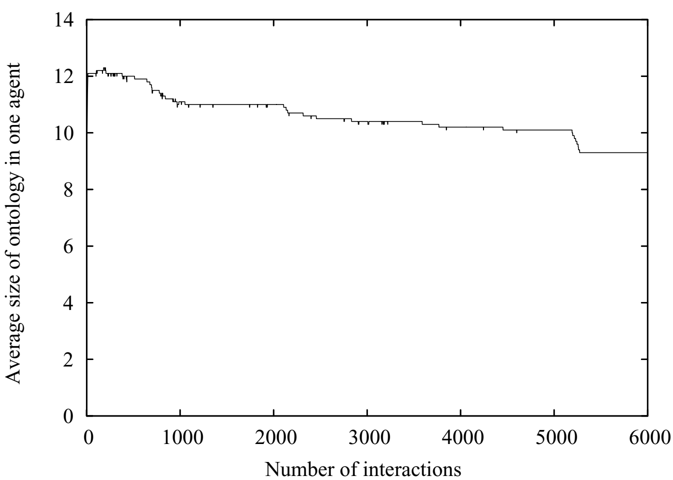

Figure 17. Evolution of the size of the temporal category repertoire of an agent averaged over all agents.

In conclusion, the experiment shows that it is possible to simulate a population of artificial agents inventing their proper language to communicate temporal information. Both the temporal category repertoire that is used to conceptualize temporal information and the lexicon that is used to express these conceptualizations are subject to evolution and are (at least partly) conventional.

6. CONCLUSION

We have argued that language is a complex dynamic phenomenon and the emergent solution of a community to the problem of efficient communication. In order to be successful in communication the members of a language community need to agree on both what to express and how to express it. As such, both the syntax and semantics of a language are in part conventional. In addition, every language user is constantly shaping his own environment and creating himself the language he is learning. Investigating language from this perspective means implementing evolutionary epistemology in the field of language research.

One way to investigate these claims is to look at natural languages and try to find proof for them. Several examples illustrating the diversity in which temporal information is expressed in different languages were given. Another way to approach these claims is to build actual systems that explain the observed diversity in a computational and plausible manner. This can be done by using techniques from artificial intelligence and computer science, which also illustrates the fact that language is a complex cognitive and cultural phenomenon and that language research requires the integration of different fields as evolutionary epistemology predicts.

First steps in building such a system for the domain of time were presented. It was shown how an agent, driven by the desire to be as clear as possible, can propose both semantic and syntactic extensions to the language. New temporal categories are introduced into the agent's ontology of time and syntactic extensions are added to his language repertoire. This was illustrated with actual detailed simulations of one agent.

It was also shown that a population of simplified agents is, through repeated peer-to-peer negotiations, capable of evolving a shared set of temporal categories to conceptualize temporal aspects of the world and a shared associative lexicon to express these conceptualizations.

There are still many issues left unsolved. For example the emergence of a more complex language with non-trivial syntax will require the introduction of more complex learning mechanisms. The emergence of tense as a grammatical system can only occur when a mechanism is found to re-use semantic and syntactic categories. It will also require that a convention to *always* specify the time frame of certain semantic or syntactic components is established.

ACKNOWLEDGEMENTS

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Evolutionary game-theoretic semantics and its foundational status

Ahti-Veikko Pietarinen*

Department of Philosophy, University of Helsinki, Helsinki, Finland
pietarin@cc.helsinki.fi

Abstract

Most of the current theories on language evolution on the market are structural and functional rather than strategic in nature, and are built upon the presupposition that it is possible to model our innate linguistic endowment and then correlate these models with some neo-Darwinian evolutionary theory. I argue that, alternatively, complex meaning relations between assertions and the world emerge from evolutionary semantic games played by the Population of Utterers and the Population of Interpreters sampled from a diamorphic population of agents. These games provide a realistic application of game-theoretic semantics (GTS) to evolutionary situations (EGTS). I will discuss the foundational status of EGTS, relating it to Ludwig Wittgenstein's language games and Charles S. Peirce's pragmatist philosophy, thus providing an alternative to adaptation in evolutionary epistemology.

1. INTRODUCTION

It is a truism to say that languages change in the given flow of time, and ample evidence from comparative linguistics has shown that modern English, French or German are quite different from their late medieval predecessors. But what is really meant by saying that languages change?

Linguists have proposed a host of answers, with little agreement on the foundational issues. Answers tend to be classified according to the types of change that one is supposed to be studying. Phonological and phonetic sound changes have been explained in terms of contextual conditioning. Grammatical change is often seen as a complex network of analogical changes in the rules of grammar itself. Semantic change has predominantly been considered from lexical points of view, based upon similar principles governing changes in the system of rules as the syntax and grammar of language. Pragmatic change

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has discovered hardly any viable principles at all.[1] Accordingly, change becomes a generic notion, subdivided according to traditional classifications of linguistics rather than being considered as a unifying phenomenon.

Such a picture is unsatisfactory for a number of reasons. It is not obvious, for instance, that semantic and pragmatic changes are parasitic on changes taking place at one of the lower levels. Nor has there been much philosophical justification in diachronic linguistics for the conclusion that changes take place in some system of regulative rules, irrespectively of whether such rules govern phonology, phonetics, grammar, word/sentence meaning or language use.

Nevertheless, the aforementioned deficiencies demarcate the kinds of foundational issues that one needs to take into account both in historical linguistics and in assessing the overall status of evolutionary theories in philosophy and in the philosophy of language.

Indeed, most of the current theories on language evolution on the market are structural and functional rather than *strategic* in nature, and are built upon the presupposition that it is possible to model our innate linguistic endowment and then correlate these models with some neo-Darwinian evolutionary theory. The problem with neo-Darwinism in the present context is that, what it perceives to be responsible for the preservation of favourable variations as well as for destroying unfavourable ones is the capacity for *adaptation* of these variations. Yet, adaptation refers to structural and functional processes which, as I hope to convey, do not form the only, and maybe not even the most plausible, paradigms for theories of language change.

In the present paper, I argue that, alternatively, complex meaning relations between assertions and the world may be seen to emerge via strategic considerations instead of structural or functional ones. Precise sense can be made of this claim by taking *evolutionary semantic games* being played on a finite domain of discourse (the *resource*) by the Population of Utterers (the System) and the Population of Interpreters (the Environment). These roles are sampled from a large, diamorphic population of agents. The emergence of the meaning relations is observed through the *stability* of players' strategies. Crucially, the notion of *fitness* represents the expected frequency of true or false interpretations, given in agents' *final interpretants*. These evolutionary semantic games provide a realistic application of *game-theoretic semantics* (GTS, Hintikka, 1973; Hintikka and Sandu, 1997) to evolutionary situations. I will denote the idea by speaking about evolutionary game-theoretic semantics (EGTS, Pietarinen, 2005a).

[1] I argue in Pietarinen (2005d) that the trouble in finding common methodological ground in the research on historical pragmatics is in the intrinsically hermeneutic nature of that enterprise.

It is worth noting that it is not clear that Darwin himself would have invariably endorsed adaptation instead of strategic processes. A passage from his autobiography is illustrious:

> I soon perceived that Selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery to me. In October 1838, that is, fifteen months after I had begun my systematic enquiry, I happened to read for amusement Malthus on *Population*, and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of *the habits of animals and plants*, it at once struck me that under these circumstances favourable variations would tend to be preserved and unfavourable ones to be destroyed. The result of this would be the formation of new species. (Darwin, 2000:42–43, emphasis added.)

Later, I will argue that the concept of a *habit* that Darwin alluded to in this passage bore the traces of the notion of strategy, which came not only to replace, but also to particularise, formalise and somewhat tone down this pragmatist notion in the wake of the emergence of modern game theory.

2. EVOLUTIONARY GAME THEORY AND LANGUAGE

Evolutionary game theory (EGT) studies the dynamics of strategic interactions of populations playing repeated games on a given resource (Maynard Smith, 1982). At the core of this theory is continuous change in strategies that the players use from one period of the play of the game to another, reflecting the variability of fitness derived from the level of success of previous rounds.

EGT has been widely applied to the analysis of language. A considerable portion of related studies focusses on computer simulations concerning iterated learning in neural networks (Batali, 1998), iterated learning in heuristically driven grammar inducers (Kirby, 2000), or 'naming games' of Steels and McIntyre (1999), to mention just a few. These and many other approaches to the evolution of language typically see the communicability function as determining the payoffs of expressions (Lewis, 1969; Hurford, 1989; Oliphant and Batali, 1996; Skyrms, 1996; Deacon, 1997; Nowak et al., 1999; Brighton and Kirby, 2001; Gärdenfors, 2004).

In strict contrast to these communicability (or performatory) paradigms, language evolution in the present context is in its semantic attributes. Moreover, in a further contrast to experimental and simulation studies, I will argue that EGT is amenable to diachronic analyses of semantics and pragmatics from the perspectives of Charles S. Peirce's and, to a degree, Ludwig Wittgenstein's philosophies. Accordingly, I suggest that the analysis of diachronic pragmatics may be initiated along similar foundational principles. The approach in the present paper is mainly conceptual and focuses on the key philosophical issues that arise at the intersection of evolution, games and language.

Nevertheless, one of the main complaints that may be voiced against the use of game-theoretic principles in addressing the meaning component of language and pragmatic issues in diachronic and historical linguistics is that games do not seem to incorporate the idea of *intended* meanings, *intentions* or even *implicatures* into their framework (Allott, 2003; Sally, 2003). They appear to model only actual interaction with explicit, manifest and identifiable actions. In other words, what does the game 'mean' in addition to such explicit, mutually testable actions that are produced in evolutionary games?

I believe that such an attempted counterargument to applying evolutionary game theory to pragmatics has been misplaced. Sight unseen, semantic and pragmatic change both operate on similar criteria and cannot thus be separated based on such criteria. Two main reasons for the inseparability of these two components of change may be identified.

First, *semantic relations* are created by the *existence* of strategies that are contested by populations of language users, namely strategies that are *winning* for one of the subpopulations. On the other hand, *semantic change* is accounted for by further requiring that these strategies are *stable* over recurring encounters.

Second, *pragmatic relations* between the interlocutors are created by the *content* of the strategies, and that presupposes a modicum of *epistemic access* to them. *Pragmatic change*, on the other hand (Jucker, 1994; Pietarinen, 2005d), is accounted for precisely as semantic change, by requiring these *very same strategies* that were in use in establishing the semantic component of language to be stable over possibly indefinitely repeating plays.

Therefore, the sole difference between semantic and pragmatic change is that the latter is linked with players' *knowledge* of the strategies in use throughout the game. Pragmatic change concerns the epistemic attitude towards the solution concepts. Intentions and the recognition and interpretation of adversaries' intentions (such as presumptive meanings or conversational implicatures) are such attitudes.

Moreover, to have genuine epistemic access to strategies is to possess a sufficiently broad, collaterally acquired *common ground* concerning the structure of the game, its payoffs, and types of the players in question.

All these requirements are readily available in the EGTS outlined below. In particular, these games are non-cooperative, perfect-information games played by two teams. Unlike in traditional game theory, no particular theory of rationality, or hyper-rationality, concerning language or players is presupposed, let alone common knowledge of rationality prone to game-theoretic paradoxes such as using backward induction as our real-life solution concept.

3. GAME-THEORETIC SEMANTICS

The evolution of the semantic component of language has received less attention than the evolution of phonology, syntax, grammar acquisition or learning. Unexpectedly, I think, given that similar game-theoretic methods have recently played a noteworthy role in formal semantics and pragmatics.

This section introduces the basic concepts of these semantic games. The next section adds the evolution.

The traditional game-theoretic approach to semantics via GTS has two players, *Myself* and *Nature*, who play the roles of the *verifier* and the *falsifier* of the expressions presented to them. Myself and Nature play a non-cooperative game on a shared commodity, which is a non-empty (possibly infinite) domain of the model. The model is an interpreted structure in which the formulas of the underlying logic or natural language are true or false, the domains of which players are to pick elements from.

As far as logical formulas are concerned, players choose individuals, subformulas delineated by sentential connectives, and non-logical constants. Moves may also refer to a wide variety of lexical and morphological categories such as modals, intensional verbs, tense operators, pronouns, definite descriptions, possessives, genitives, prepositional phrases, eventualities, adverbs of quantification, aspectual particles, polarity items and so on.[2]

As far as natural language is concerned, any sentence of English defines a game between Myself and Nature. Myself strives to show that the given sentence is true in a given model, and Nature strives to show that the sentence is false in it. The game rules for the quantificational expressions such as *some*, $a(n)$, *every* and *any* prompt a player to choose an individual from the relevant domain (a choice set) I, labelling the individual with a name if it does not already have one. The game continues with respect to an output sentence defined by the game rules.

Analogously with semantic games for formal languages, a play of the game terminates when such components (roughly corresponding to atomic formulas) are reached in which further applications of game rules are no longer permitted. Their truth in a given interpretation determines whether Myself (atomic truth) or Nature (atomic falsity) wins.

[2] For studies concerning semantic games for these and other expressions, see Hintikka & Kulas (1983), Pietarinen (2001).

An example of the game rule for *some* is as follows.

(G.some): If the game has reached a sentence of the form

X—some Y who Z—W,

then Myself chooses an individual from I, say b. The game continues with the sentence

X—b—W, b is a Y, and b Z.

Here *who Z* (or *where Z*, *when Z* etc.) is the entire relative clause, and the main verb phrase W and the head noun in Y are in the singular. For simplicity, the relative clause markers are often omitted. X marks linguistic context.

Another example is for negation:

(G.not): If the game has reached a sentence of the form *neg*(A), the players exchange roles, and the winning conventions will also change. The game continues with respect to A.

The operation *neg*(A) is a functor forming sentential negations of A.

Furthermore, for *any* the game rule is dual to **(G.some):**

(G.any): If the game has reached the sentence

X—any Y who Z—W,

then Nature may choose an individual, say b. The game is continued with the sentence

X—b—W, b is a Y, and b.

Legitimate moves are thus determined by the nature of the constituent expressions under evaluation. Since natural-language sentences and logical formulas are written linearly, the direction of the evaluation is typically from left-to-right, right-to-left or top–down, and in two-dimensional heterogeneous systems, such as graphs and diagrams, from the outside-in (Pietarinen, 2005c). Finally, the surface structure of natural language is produced.

Semantic games may be thought of either as in their *normal* or in *extensive form*. In normal-form games, the strategies correspond, logically speaking, to Skolem functions, namely mathematical entities expressing functional dependencies between logical expressions. In extensive-form games, the root is the complete expression and the terminal histories are labelled with atomic formulas or simple linguistic items. Extensive-form games are finite trees, but unlike derivational phrase trees, they are semantic.

Atomic expressions are interpreted prior to evaluation, so that they receive either the truth-value *True* or the truth-value *False*. The payoffs assign to strategies in normal-form games and to terminal histories in extensive games. An n-tuple of Skolem functions or a strategy profile in the extensive game, which invariably leads the player whose role at the beginning of the game is the verifying (resp. falsifying) one to the winning terminal position interpreted as *True* (resp. *False*), will be his or her winning strategy. The existence of such strategy profiles shows when a compound formula, a sentence of natural language or a segment of discourse is true and when it is false in a given model.

GTS carries with it a couple of further assumptions. Just as in the traditional theory of games (von Neumann and Morgenstern, 1944), the players are hyper-rational optimisers. Furthermore, semantic games are static one-off games, having a finite horizon because the input strings are finite in length. Strategies are pure, and in terms of the conditions for the truth of the expressions, Nature's function remains stationary. In addition, the game and its equilibrium are common knowledge. We address these concerns as we proceed.

4. EVOLUTION IN SEMANTIC GAMES

In this section, we marry evolution with semantic games. The main worry concerning assigning meaning (or semantic attributes) to sentences of language or logic via the traditional approach to GTS is that winning strategies equate with what may be called the *weak* senses of equilibrium points. In other words, winning strategies refer to such terminal nodes that are among the equilibria if the game is played once, but in case of being played repeatedly (possibly over infinite encounters), may nonetheless fail to satisfy some further requirement such as stableness. The *strong* notion of equilibria as stableness of winning strategies motivates the introduction of evolutionary superstructure.

The reason for taking multiple plays of semantic games into account is that each such game will in actual situations of language use get to be played in changing, fluctuating environments with endlessly variable contexts.

We begin by reviewing some of the basic concepts of EGTS.

4.1. Communication is Non-Cooperative

One of the foremost decisions is whether we want our games to be *cooperative* or *non-cooperative*. The Gricean tradition sees communication as a cooperative enterprise, grounded on normativity of mutual understanding (Grice, 1989). Semantic games are, in contrast, non-cooperative.

The conceptual tension with the notion of cooperation is that the Gricean notion of cooperation is not equal to the game-theoretic understanding of cooperation. Even if Grice's cooperative principle were, to some extent at least, preserved in conversation, the reason of why it is different from the game-theoretic conception is that Grice's definition of cooperation (according to which speaker's contribution ought to be such that is required by the accepted purpose of the exchange) is speaker-oriented and says little about the actual complex process of interpretation.

On the other hand, in game theory, (according to which players' roles are, in normal cases, symmetric in the sense that no one cooperates less than the others), Grice's cooperation would not be interactive cooperation. Nor, clearly, does cooperation in Grice's sense refer to any folk-linguistic notion of carrying conversation on in tandem through something like the accustomed behaviour of the speakers and hearers.

Here we see the reason for the cooperation in the game-theoretic sense being quite different from the cooperation in the sense in which Grice defined it. Economics does not attempt to model how agents communicate with each other, because agents are assumed to endorse joint action and any communication is relegated to pre-play situations. Such games are better viewed as coalitional. Likewise, Grice's cooperative principle could perhaps be renamed along the lines of the 'principle of required (or expected) contribution', in which by contribution it is referred to those parts and fragments of input an agent brings in to increase the *summum bonum* of linguistic communities.[3] When the presumptions are not met, the sole possibility of creating mutant strategies may alert the community to check if anything needs to be done to adjust the language-world associations, in other words the strategies by which such associations endure in these communities.

Moreover, it is not clear that communication and linguistic exchange is, or ought to be, cooperative in order for its components to be optimally understandable. Dessalles (1998, 2000) maintains that even if both sides agree on precise rules, they may be pursuing quite different goals. However, Dessalles appears to confound cooperation and competition. To pursue even strictly opposing goals may still admit cooperation in achieving the goals, as happens in variable-sum games. On the other hand, to attain the same goal may be perfectly possible through entirely independent (say epistemologically and causally independent) decisions.

Stronger and more viable evidence for non-cooperation in the construction of evolutionary meaning falls from the well-established fact that any cooperative setting may be rewritten in terms of a non-cooperative game, because the cooperative acts such as negotiation may be pursued preceding the strategic interaction.

The potential in dealing with communicative aspects of behaviour and reaching understanding has nevertheless been recognised ever since the early phases of the formation of the theory of game:

> Even if the theory of noncooperative games were in a completely satisfactory state, there appear to be difficulties in connection with the reduction of cooperative games to noncooperative games. It is extremely difficult in practice to introduce into the cooperative games the moves corresponding to negotiations in a way which will reflect all the infinite variety permissible

[3] The normative nature of the *summum bonum* was also Peirce's key occupation. Pietarinen (2005b) investigates further parallels between Peirce's and Grice's philosophies.

> in the cooperative game, and to do this without giving one player an artificial advantage (because of his having the first chance to make an offer, let us say) (McKinsey, 1954: 359).

The infinite variety permissible in cooperative games is precisely the kind of problem we encounter in studies of formal pragmatics, which not only has to deal with conventional signs but, among other things, also interpretants of indexical and iconic signs. They are very difficult to be reduced to some formal framework of contingent but observable behaviour.

Even more candidly, thirty years later Shubik (1985: 293) reiterates this point, suggesting that:

> In much of actual bargaining and negotiation, communication about contingent behaviour is in words or gestures, sometimes with and sometimes without contracts and binding agreements. A major difficulty in applying game theory to the study of bargaining or negotiation is that the theory is not designed to deal with words and gestures—especially when they are deliberately ambiguous—as moves. Verbal sallies pose two unresolved problems in game-theoretic modelling: (1) how to code words, (2) how to describe the degree of commitment.

Summarising, language use unearths a rich frontier for strategic interaction, probed only quite recently. Given the problems in translating cooperative games into non-cooperative ones, and given that an established tradition exists, albeit in the minority, to view evolutionary games as non-cooperative, we might be better off in following that minority.

4.2. The Prerequisites for Meaning not Social

Even if there were some degree of cooperation in language usage, it does not follow that meaning would be social in some inherent sense. This is not to say that social factors are void or altogether dispensable in language evolution; such factors do vary with cultural and biological feedback. It is nonetheless doubtful whether cultural, biological, ethnographic, anthropological, or neuropsychological data play a central role in the theoretical question about the origins and development of the very semantic relations behind linguistic acts. The reason is that little is lost in dropping such excess assumptions from the theory. Understanding the evolution and emergence of social communication entails the much broader semantic and pragmatic understanding of communication, not vice versa.

In ruling social aspects out of the scope of evolutionary games, language use by no means becomes irrelevant or trivialised: factors such as speaker's meaning as distinct from literal meaning, the context of the utterances, the role played by the changing environment, the background information and beliefs, performatives, presumptive meanings and so on, are crucial in steering the evolution of meaning. Nevertheless, it is a long conceptual step from pragmatic theories of language use to the convincing argument that the defining characteristics of language would be inherently social. I do not see that gap to have been filled in recent literature on language evolution.

4.3. Semantically Stable Strategies

Let G be an asymmetric game, and let the payoffs be functions $\mu : (\Phi \times S) \to \{1, -1\}$ from a set of *signs* Φ and the set of *strategies* S to positive and negative *interpretants*. Signs carry sentences, propositions, utterances, non-linguistic expressions, diagrammatic, graphical, visual, haptic or auditory representations or any other stimuli.

Let the set of players be the population i of diamorphic agents playing pure, deterministic choices in G, adopting one of the two common strategies. Populations are thus not coalitions, but rather *teams* as in team theory (Marshack and Radner, 1972). The members of the population i are playing either the role of the verifying player V or the role of the falsifying player F, determined by the type of sign under evaluation. The strategies are dissected accordingly.

The sign is a part of the sampling process of members from a large population. During each *period* t of positive integers in which the game G is played on signs $p \in \Phi$, a pair of members of the population is sampled to function as the *Verifiers* V and the *Falsifiers* F of the sign p. The members are informed about their own roles. The agents retain histories $h \in H$ of G transmitted from any earlier game at $t-1$ to the game at t. The *role switches* are denoted by the function $R : (\Phi \times H) \to \{\uparrow, \downarrow\}$ from signs and histories of G to the set of binary values. R denotes those histories $h \in H$ in G at any period t where the role is to flip from the verifying role to the falsifying one, or vice versa. This happens when some negative sign (other than contradictory negation, because it is not game-theoretic) occurring in $p \in \Phi$ is uttered.

Let ρ be a mutant strategy and let $\sigma^* = (\sigma^*_V, \sigma^*_F)$ be a strategy for team i from which two opposing players are sampled, σ^*_V being the strategy for any member of i called upon to play the role V, and σ^*_F being the strategy for any member of i called upon to play the role F. The strategy ρ is considered *mutant*, its purpose being to invade team i. Since G is asymmetric, some mutants may affect the behaviour of the players of only one role.

The purpose is to show which p's are *semantically stable* among the population i. By following customary theory of evolutionary games, we define the strategy σ^* as semantically stable if and only if (i) σ^* is a best reply to itself, and (ii) σ^* is a better reply to all other best replies ρ' than these are to themselves (Maynard Smith, 1982). We may also assign probability measures

Δ on the set of strategies S by defining vectors of frequencies with which the populations play each of the different strategies in S.

Because G is asymmetric and may be embedded in the larger symmetric game G', σ^* is an evolutionarily stable strategy of the symmetric version G' of G if and only if σ^* is a strict Nash equilibrium of G. A strict Nash equilibrium is a situation in which a player can only do worse by changing strategies. It provides a solution concept for G that is hard to destabilise if every player has a strict incentive to maintain his or her own behaviour.

4.4. *Truth Versus Meaning*

Game-theoretic approaches to semantics assimilate truth and meaning, but at the same time enrich both by introducing strategic processes as the mediators between language and the world. Such assimilation is no longer viable in theories of language evolution that need a more diverse notion of meaning. Words, sentences and segments of discourse appear as pieces in a larger puzzle of rule-governed social behaviour, and meanings as roles in the context of conversational language use.

By introducing evolutionary pressures to the fixation of meanings, we in fact drive a sharp wedge between truth and meaning. While both are dependent on the continuum of populations that enter evolutionary situations, they part company in the separation of stable strategies and the sequences of actions assigning values to signs. One cannot observe meaning from any single series of actions alone. One also needs to know what it is to end up with certain payoffs, or final interpretants, at the point in which the interpretation terminates. One needs to know the purpose and goals of actions. To describe a strategy is to put forward the general layout of the actions that it gives rise to. To implement it is to communicate what a sign means.

This point is made more precise in viewing games in their extensive forms.

4.5. *Extensive-Form Evolutionary Games*

Stable strategies are not the sole solution concepts for semantic language-games. They insist on strict Nash equilibria and try to narrow down the number of such points in repeated plays. But interpretation is a process based on sequential, interactive turns of actions and reactions over long periods of encounters. For this, extensive forms of G that bring out the subgame structure and successive responses to adversaries' choices tend to be more appropriate (Cressman, 2003).

I will not reproduce the full definition of extensive games here (Pietarinen, 2004). Briefly, they are trees of finite length but possibly of infinite branching factor if the domain is infinite. Each non-terminal history $h \in H$ is labelled with a non-atomic subformula of the given logical expression or a segment of language, and each terminal history is labelled with an atomic formula or a terminating expression. Terminal histories come with the payoff structures. Vertices from one history onto its extension are labelled with actions, which can be objects of the domain, subformulas, or instructions to change roles.

It is not, however, obvious how to extend the concept of stableness in asymmetric games to cover extensive games: one problem is that information sets may lie at off-equilibrium paths reached with very small or zero probability. In addition, whether one can dispense with the assumption that every player has at most one history along each period t of plays of an extensive game is an open question, and so is the question of the right amount of derivational information that players should be able to garner from histories belonging to the periodical past. We must omit further discussion concerning these points in the present paper.

4.6. A Case Study: Anaphora

As noted, extensive-form representations contain information that is often omitted in the normal form representation. Such information is needed in accounting for many pragmatic phenomena, such as in creating suitable *anaphoric relations* (cf. the discourse *A man sees a dragon. He escapes.*). What the suitable or intended value of the anaphoric pronoun *he* is, is often found in the past discourse referring to some earlier derivational history of that discourse (*a man*).[4] There is no way of recovering that information merely from the normal form representation of the game (Janasik and Sandu, 2003; Pietarinen and Sandu, 2004). Extensive games are essentially diachronic, a property that is acutely needed in interpreting anaphora.

However, in interpreting anaphora more is needed than just the record of derivational histories and access to earlier choices made in the game. Players also need access to information concerning strategies that they themselves or their adversaries have entertained in earlier parts of the game. For that to be possible, we extend the extensive-form of a game to what we have termed *hyperextensive-form games* (for details, see Janasik et al., 2003; Pietarinen and Sandu, 2004). These games code the information concerning the strategies that players have used earlier in the game into the local states of the players at each non-terminal history in which a player is to move. Hyper-extensive forms account for functional anaphora in sentences such as

[4] I say ‘often’, because not all pronouns have heads: “Of course there is live music in our night-club. Unfortunately, tonight they have a night off”.

"Every man carried a gun. Most of them used it". Here, the values for *the gun* and *it* are given by a function from men to guns, producing for each man, a particular gun.

Furthermore, as soon as pragmatic change is at issue, even a greater modicum of diachronism than just access to earlier actions or strategies made in the extensive or hyper-extensive game is needed. Players need to have access to actions and strategies emanating from earlier plays of the game, too. This transfer of information from earlier plays to future ones is the main reason behind pragmatic change: as each game is played within a changing environment, there is bound to be variation in the strategies from one play of the game onto another.

There are thus two levels of diachronism in language evolution: there is the more semantically oriented, but not exclusively semantic question of *game-internal references* to past actions, and the *trans-structural question* of the amount of information concerning actions transmitted from the earlier periods to the future ones. Pragmatic features per se are not subordinate to the latter kind of time constraint, and may involve shorter intervals that take place within single runs of the games. However, the evolution and change of such features is parasitic on aspects of evolutionary dynamics in sequences of periods comprising total extensive games, because only then the games get to be played in several, changing and mutating environments and contexts that nurture the meaning.

Interpreting anaphora thus becomes the matter of a relative accessibility of the information concerning either the choices of individuals or the use of strategies, in which the accessibility of information pertains either to earlier parts of the same semantic game (intra-structural pragmatics), or to the histories of earlier plays of games (trans-structural pragmatics), both in the sense of the extensive forms of EGTS that bring out the full subgame structure.

To coin a slogan, pragmatics is, from this perspective, "games minus equilibria". The evolution of pragmatic aspects of language is what happens in several repetitions of such games that no longer disregard phenomena out of classical solution concepts.

4.7. On Rationality and Habits

It is in the nature of evolutionary games that the players do not act consciously and do not deliberate rationally when they are to move. Yet some sense of intelligence and residual rationality devoid of self-reflection is needed. The nature of such concepts depends on the status of strategies in evolutionary games.

Instead of speaking about strategies, I believe that these conceptual issues would be clarified if the 19th-century terminology of speaking of *habits* of agents were to be revived in the contemporary context of evolutionary games. After all, originally habits were not restricted to rational beings. As much as they were seen as psychological (habits as dispositions), attitudinal (habits as beliefs) or strategic (habits as general plans of action), they were also viewed as responsible for physical aspects of nature (habits as regularities).

But if so, then the existence of physical habits provides a shortcut to what Immanuel Kant and others termed the 'transcendental argument' for the existence of identifiable regularities in the world. In other words, our ability to speak, think and function in our environments in virtue of our habits is linked with the habits that transpire in nature.

Closer to our linguistic concern, action as such lacks generality and thus cannot functions as a proper interpretant of assertions. According to Peirce, however, habits can only be described by referring to their extraneous output, namely actions themselves, *"with the specification of the conditions and of the motive."* (Peirce, 1931–1958: 5.491) Likewise, the content of strategies is largely inexplicable even in game theory, which focuses on outlining the structure of games in terms of actions that have been performed. Likewise, strategies are general rules of action, not consisting in actions or exhaustively described with reference to them.[5]

This difference relates to the distinction between truth and meaning, and is reflected in extensive games as the difference between the sequences of actions (and the ensuing possibility of the existence of winning strategies) and the content of the strategies in use throughout the game.

There are further links between habits and strategies, such as the following statement from Peirce: *"Now, the identity of a habit depends on how it might lead us to act, not merely under such circumstances as are likely to arise, but under such as might possibly occur, no matter how improbable they may be (no matter if contrary to all previous experience)."* (Peirce, 1931–1958: 5.400) The idea that one needs to take all "would-bes", all possible future courses of events, even those that have zero probability, into account, is preserved in

[5] It is vital to acknowledge that the concept of a habit was frequently used for explanatory purposes in sciences in the 19th century and earlier. It was thought to be the key to many doors of philosophy, not only for philosophers from David Hume (1711–1776) and Kant to 19th century pragmatists including John Dewey (1859–1952) and James, but also (and more commonly) for a number of political and social scientists, psychologists, institutional economists, and biologists throughout the 19th century and the early 20th century. Camic (1986) traces some of the sociological history of this fascinating concept from the past, with a fleeting look back at its philosophical significance. He makes no mention of Peirce, but on page 1046 notes that Dewey had considered habit to play a considerable role in pragmatics, being the dynamic and projective systematisation of human action. James gave it a psychological twist, which perhaps comes closest to what we nowadays understand by it, but which is not to be confounded with Peirce's understanding (Pietarinen 2003).

strategies that prescribe actions also to histories that will not be reached by following that strategy.

There is more in the linkage between habits and strategies. That the separation of one population into randomly drawn pairs playing opposing roles is the right model for language interpretation is shown by the reasonableness of thinking one agent of the team (or the phase of a 'quasi-mind') as sometimes uttering and sometimes interpreting a sign. Whether such roles are actually found in nature among actual language users, or how the process of sampling produces pairs of agents that agree to such polarised roles as if by miraculous coincidence are irrelevant, since the theory does not assume real agents that deliberate on their roles. In other words, even if the theory were applied to actual language users (or some computational simulation of them thereof), they would not make conscious choices concerning what sets of strategies to use.

Such strategies are parts of agents' habits, those innate rules, responses, guides, customs, dispositions, cognitive conceptions, generalisations and micro-institutions that have influenced them through evolutionary time. In fact, habits are constituted through time. This is, of course, in perfect accordance with the much recent evolutionary and game-theoretic arguments employed in biology. Quoting Plotkin here, *"The ordinary meaning of the term 'behaviour' is even wider; its root is the Latin verb habere (to have), so that its common meaning extends to 'having possession of' and 'being characterised by'. Now, behavioural biologists simply never use the words in these senses."* (Plotkin, 1994: 103)

4.8. On Stability

Perturbations may be seen as special moves in the game made by mutants. Stability is, in this sense, closely related to the tendency of populations to resist external disturbances and to strive to remain in a state of equilibrium. This withstanding of changes is essential in stability, but it also involves qualitative considerations concerning the degree in which stable strategies can withstand external disturbances, in other words the intensity or aggressiveness in which those adversary strategies strive to push the plays off the equilibrium path.

The analogy of such an understanding of stability with the semantic and pragmatic change is this. Moves according to which links between language and the world are established—and according to which not only the truth-conditional meaning of expressions but also their meaning in terms of the use of these expressions in the environment in which the games are played—combine the non-deliberate, unconscious and unaware actions that the players of evolutionary semantic games perform with the structural tendency of strategies to resist small, unessential changes.

Aside from stable strategies withstanding external changes we need *resilient stability*, which refers to agents' capacities to re-establish the internal structure of strategies after the occurrence of mutants that have performed some perturbations to the intended plays. It correlates with rationality in those situations in which sub-optimal actions amount to better payoffs than those made according to traditional solution concepts such as backward induction. Skyrms (1996) argues that from the evolutionary perspective, this is as it should be: non-optimal systems may well be resistant to invasion by mutants.

These different senses of stability as well as different senses (or the lack thereof) of rationality have not been carefully distinguished from one another in arguments for using evolutionary games in showing how elementary grammar systems may have evolved. In evolutionary semantic games, there is little room for the traditional idea of rationality. Stability, on the other hand, may come in different shapes and colours. The 'no change' situation is one version of stability in which no mutants arise and in which there is no need for a change in the meaning of expressions. Few living languages actually in use seem to have semantics that is based on such understanding of stability as invariability.

Resilient stability surfaces in cases in which communication is well established, and in which hearers perform different strategic 'hear-acts' such as accommodation and relevance for the sake of keeping mutual understanding optimal. Manifold qualitative aspects of resilient stability make it much more complex to pin down. Important parameters here are the time and amplitude of the disturbance in meaning in recovering from out-of-equilibrium thrusts. This understanding of stability appears more common in natural-language meaning change.

4.9. Complete Information, Common Ground and Salience

The last point that we take up in this section looks forward to one of the main philosophical imports of our framework. It was assumed, quite implicitly thus far, that evolutionary semantic games are ones of complete information. This means that the structure of the game, including the payoffs of the game, is completely known and common knowledge to the players. But if so, then there inevitably is at least some amount of regularity in the world, since one does not need Nature to make random deals at the start of the game (or, for that matter, in the middle of the game) in order to deliver a probability distribution of players' types. Complete information, and common knowledge of it, is what defines the common ground of the players without which sensible communication would not be possible.

In fact, as early as in 1908, Peirce recognised the necessity of such a common ground, remarking in an unpublished paper, *"No man can communicate the smallest item of information to his brother-man unless they have . . . common* *familiar knowledge; where the word 'familiar' refers less to how well the object is known than to the manner of knowing. . . . Of course, two endless series of knowings are involved."* (Peirce, 1967; Manuscript 614: 1–2) The qualification 'familiar' concerning common knowledge refers to the *degree of knowing* rather than to a *way of knowing*.

The qualification suggests further that, what constitutes the common ground for Peirce are, contra Stalnaker (1974), not presuppositions *as propositions* but the habitually grounded familiarities and attitudes with *entities* of different sorts. In Peirce's comment we also find an anticipation of the notion of common knowledge as it was crafted in Lewis (1969) to make systems of communication function and to give rise to simple systems of language through attempts of coordination.

Accordingly, some common ground is needed in the system in order for a language to evolve. Semantic games suggest an answer to what a useful notion of the common ground is. The players are mutually acquainted with the universes of discourse from which they are to choose. A sign can be communicated only if suitable familiarity with it obtains, through acquaintance or instinctive and innate knowledge, for instance, or as Peirce held, through both factual and conceptual collateral observation and experience plus an understanding that the other party is also appropriately and similarly familiar with such knowledge. This does not mean that communicators are perfectly informed about the domains; they might be able to preview only fragments of them at a time. Furthermore, the domains need not be finite. Thus learning is essential. Various notions of learning may indeed be encoded into the strategies that the players use. For example, we may require them to be recursive and learnable in terms of formal learning theory.

This has a bearing on the concept of *salience* that Lewis and others have argued to be indispensable in order for a conventional system to evolve. Salience has rarely been incorporated into game-theoretic analyses. It has more readily been argued in evolutionary games that organisms need not recognise whether one type of behaviour is more successful than another, because they are genetically pre-programmed to act. Likewise, in semantic games, signs may be communicated and elements of domains selected without identification of actions, or of precisely what the practical effects of what they amount to are.

The point is also related to Peirce's understanding of the concept of a habit, that general organisational principle that all sign bearers, humans and non-humans alike, are prone to possess and educate. It is thus not merely an embellishment to say that we find some contemporary correlates of this forgotten idea in evolutionary strategies, be they about focal or other stable points of meaningful interaction.

To put the point other way around, if the environment within which the language games are located had no identifiable regularity, then it is dubious whether we can at all achieve the tasks of speaking and communicating, or even thinking or being self-conscious and aware. Even further, the concepts of truth and falsity might no longer be attributable to propositions or assertions, however indubitable or certain they would appear to be.

5. PHILOSOPHICAL SUMMING-UP

Among the foundational and conceptual fallouts of having evolutionary structure to GTS are the following five points.

5.1. No a Priori Knowledge

Given a potentially infinite period of time, repeated transmission of information from individual sets of plays in semantic games to further sets of plays represents a process by which one comes to *know* (or *believe*) the content of linguistic assertions. There is no a priori notion of such knowledge in evolutionary games, even though factual and conceptual information is present.

The players have, however, complete knowledge concerning the payoff structure of the game, and there are no hidden chance moves by Nature. This makes communicating linguistic information possible, via the common ground established by the common familiar knowledge concerning the structure.

On the other hand, players have no perfect foresight concerning the future actions, including the set of immediately available actions presented to them when planning the moves. Limited foresight is essential in evolutionary game theory and could be adapted to other game-theoretic uses concerning language and logic.

Moreover, *ignorance* (partial interpretation of formulas, i.e. the case that a proposition is neither true nor false in a model) emerges because the two players, the Inhabitant and the Late-Comer, may both withdraw from the resource. Logically, this may be thought of as a natural proviso for the failure of the law of excluded middle.

5.2. Evolution of Semantics

Semantic change is attained through evolutionary games. Such a change does not pertain to the evolutionary emergence of rule systems (which is not our concern here, as the game rules are fixed and immutable, cf. e.g. Nowak et al., 1999 instead), but to the evolution of strategies that propagate in repeated dynamic games.

5.3. Changes in Language Games are Evolutionary

In strict relation to the previous point concerning semantic change, we get an explication of Wittgenstein's notion of *change in a language game through time* that he presented in *On Certainty* (1969). Strategies governing language change are strategies governing human behaviour. That some meanings get endorsed in populations is due to the existence of semantically stable strategies in EGTS, in other words those that do well against themselves and against mutant meanings. The more stable a strategy is, the less context or collateral information shared by the players is needed in interpreting assertions. A semantically stable strategy is the evolutionary counterpart to the material truth of assertions.

The upshot is that these games call for a re-examination of some of the basic assumptions in game theory. They make public some fundamental hidden assumptions concerning the received notion of a game in the theory of games. Applying the viewpoint of *On Certainty*, in which the notion of knowledge depends a great deal on factual information, it is not sufficient for players to simply know or even believe what the available actions are. They should also be able to demonstrate that they are *in the position to know* or believe them. This makes all the difference in using and applying the concepts such as knowledge, belief and expectation in the search of new solution concepts for games with complex information structures.

My approach is thus also distinct from the 'naming games' of Steels and MacIntyre (1999). Following Wittgenstein's ingenious example, naming is not yet a genuine, let alone complete move in language games.

5.4. Evolution of Pragmatics

We also get an explanation of some features in the evolution of pragmatic aspects of language. For instance, interpreting anaphora is the matter of a relative accessibility of the information concerning either the choices of individuals or the use of strategies, in which the accessibility of information pertains either to earlier parts of the same semantic game, or to the histories of earlier plays of games, both in the sense of the extensive forms of EGTS that bring out the full subgame structure.

Accordingly, the much sought-after distinction between semantics and pragmatics (Turner, 1999; Wierzbicka, 2003) dissolves into the distinction between the non-epistemic/epistemic access to strategies hovering at the back of both semantic and pragmatic meaning relations between language and the world.

Elsewhere, I have argued that historical pragmatics is essentially hermeneutic inquiry and so runs the risk of falling into the trap of hermeneutic circle

(Pietarinen, 2005d). However, as soon as we think of the strategic interpretation of text or ancient artefacts as evolutionarily constrained and evolutionarily guided, pragmatic activity, the kind of hermeticism involved in historical pragmatics no longer needs to detain diachronic arguments that are in use in pragmatics.

5.5. Seeking and Finding Habitual Activities

Notions such as seeking and finding of suitable individuals (Hintikka, 1973) when performed to satisfy a predicate term are evolutionary activities guided partly by reason and partly by habitual responses to environmental signals. Accordingly, in place of strategies, the rules that guide action are better termed agents' habits, to follow the practice of pragmatist philosophy.

Moreover, the non-cooperative evolution of semantics is not, *pace* Lewis (1969), an instance of the evolution of conventions but of the habit-change in individuals. Parts of strategies from parental games are 'projaculated' to offspring to detain that change. Thus both *inheritance* and *imitation* are covered by this approach, because strategies (or habits) are, if we observe the pragmaticist perspective, operative in human beings as they are operative in nature. But if so, then we have answered one of the central questions in evolutionary epistemology (EE).

6. EVOLUTIONARY EPISTEMOLOGY, AGAPISM AND PEIRCE'S PRAGMATICISM

The phrase 'evolutionary epistemology' has been routinely attributed to Campbell (1974). Let us recall, however, that in *Evolutionary Love* (Peirce, 1931–1958: 6.294, 1891), Peirce sets out to describe his approach to metaphysics, which, in essence, was that the universe consists of continuous processes, not things, and that these processes are continuously connected. Thoughts and intellectual ideas alike are instances of such *synechist* processes. The universe is governed by three interrelated principles: absolute chance, mechanical necessity, and their 'synergetic' evolutionary love, *agapism*, of which chance and necessity are degenerate forms. Chance begets order, and order begets laws. Chance, the disorderly property of the *chôra* of the universe, cannot and ought not to be explained by any theories that we possess. But laws, including natural laws, are not immutable and eternal. They are evolutionary. They are 'habits of cosmos' just as logical truth of a proposition is a habit of its assertor. Habits grow. Universes are progenies or experiments in which laws of the most fundamental sciences are contested, challenged and litigated. We happen to live in one of them. Others, where physical or biological constants may have had different values, had different regularities and irregularities, and were not so lucky and did not survive.

The epistemology that lurks behind this metaphysical depiction links with EE but is not equivalent to it. EE maintains that natural selection is the key component in sustaining the reliability of the senses and the cognitive mechanisms through which we acquire knowledge. According to agapistic epistemology, sensory organs or neural structures are not principally subject to adaptation according to selective mechanisms, as they are in a continuous interaction and cyclical causal relations with one another. In as much as our organs are affected by their environments, they also affect the environment. There is a two-way dependence. Mutual affection needs to find balance, and this craving for balance agrees with the key principle of agapism, that of a proper conduct of an agent in its environment that puts its own interest last for the sake of others.[6]

The prospects of agapistic evolutionary philosophy were not rosy. Just as the idea of a habit, it was soon superseded by utilitarianism and neoclassical economics promoting free market, bolstered—not entirely justifiably, because of the omnipresence of chance and the possibility of performing 'trial-and-error epistemology'—by the Darwinian theory of evolution.

Therefore, a crucial difference exists between the Darwinian model of evolution and the Peircean one, the latter of which I believe to be a preferred one for linguistic change. In language, agapism should take the key place of adaptation. Evolution of meaning and communication is much more than just maximisation of expected utilities, the 'Gospel of Greed' that greatly worried Peirce, the widespread tendency that bulks large given a sufficient span of time, energy, intellectual capital and labour. Instead, agapistic evolution has a lot to do with the overall methodology of scientific inquiry, and is thereby linked with the *speculative rhetoric* of Peirce's logic and semeiotics, namely the science of how signs are linked with their interpretants. Modern pragmatics is a part of this wider enterprise.

In addition to agapistic conception of evolution, abductive reasoning sees to it that only plausible hypotheses are to be considered, much in the same way as chess masters come to consider only a tiny fragment of possible scenarios. The means of doing so have been implanted into humans during the millennia of their existence, and in this historical development their habits have been nurtured and methods evolved that block the generation of *any* (that is, any

[6] We need to bear in mind that Campbell (1987) does refer to Peirce's evolutionary metaphysics, although not discussing it in depth. See also Millikan (1984) for an alternative proposal to apply evolutionary arguments in the philosophy of language and mind. Cosmides (1989) adduces some experimental evidence on the possibility of natural selection affecting human logical reasoning.

conceivable but implausible) hypothesis. This historical part of inquiry is governed by chance (Peirce's *tychism*), necessity, and their synthesis, and is thus related to the habitual evolution of natural laws in a like manner as it is related to principles governing the change in linguistic meaning.

7. CONCLUSION

Evolutionary GTS differs from other evolutionary arguments in the key sense of not focussing on how different rule systems might evolve, but on how stable meanings evolve and transpire among populations of agents. It puts strategic aspects of semantic and pragmatic change into a formal and systematic perspective and correlates both with pragmatistically inclined EE akin to Peirce as well as to Wittgenstein's language games and his diachronic approach pragmatic phenomena in language.

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Towards a quantum evolutionary scheme: Violating Bell's inequalities in language

Diederik Aerts

Leo Apostel Centre, Free University of Brussels, Brussels, Belgium
diraerts@vub.ac.be

Marek Czachor

Faculty of Applied Physics and Mathematics, Politechnika Gdanska, Gdansk, Poland
mczachor@pg.gda.pl

Bart D'Hooghe

Leo Apostel Centre, Free University of Brussels, Brussels, Belgium
bdhooghe@vub.ac.be

Abstract

We show the presence of genuine quantum structures in human language. The neo-Darwinian evolutionary scheme is founded on a probability structure that satisfies the Kolmogorovian axioms, and as a consequence cannot incorporate quantum-like evolutionary change. In earlier research we revealed quantum structures in processes taking place in conceptual space. We argue that the presence of quantum structures in language and the earlier detected quantum structures in conceptual change make the neo-Darwinian evolutionary scheme strictly too limited for Evolutionary Epistemology. We sketch how we believe that evolution in a more general way should be implemented in epistemology and conceptual change, but also in biology, and how this view would lead to another relation between both biology and epistemology.

1. INTRODUCTION

In this article we will demonstrate the presence of quantum structures in language by proving the violation of Bell's inequalities.[1] Apart from any specific philosophical theory about language, the presence of quantum structures in language is an interesting finding, particularly to the community of scientists

[1] Bell-inequalities are a set of mathematical inequalities that have been derived with the aim of testing experimentally the presence of quantum structures within the data structure of an arbitrary source (see section 2.4).

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who study the structure of language, and also to those who investigate the working of the human mind, language being one of the mind's major products. In addition to this first-order motivation—as one could call it—the search for quantum structures in language was equally well guided by the aim of elaborating the *global worldviews construction program*, which is the main theme of research in the Leo Apostel Centre (CLEA) (Aerts et al., 1995; Apostel, 1995). It is through its relevance for the global worldviews construction program that the material presented in this article becomes relevant for Evolutionary Epistemology (EE), certainly in the broad interpretation that EE was given at the conference where we presented the material of this article. The Stanford Encyclopaedia of Philosophy defines EE thus:

> EE is the attempt to address questions in the theory of knowledge from an evolutionary point of view. It involves, in part, employing models and metaphors drawn from evolutionary biology in the attempt to characterise and resolve issues arising in epistemology and conceptual change. There are two interrelated but distinct programs, which go by the name EE. One focuses on the development of cognitive mechanisms in animals and humans. This involves as straightforward extension of the biological theory of evolution to those aspects or traits of animals which are biological substrates of cognitive activity, e.g. their brains, sensory systems, motor systems, etc. This program has been labelled EEM. The other program attempts to account for the evolution of ideas, scientific theories, epistemic norms and culture in general by using models and metaphors drawn from evolutionary biology, and it has been labelled EET.

EE is sometimes given a narrow meaning, according to which it is said to attempt to model epistemology not merely in terms of biological evolution but rather in terms of the neo-Darwinian version of biological evolution, basing itself on the assumption that it is this neo-Darwinian version that can be transferred to epistemology. The broad meaning of EE is that the inspiration for modelling epistemology remains biological evolution, but the neo-Darwinian form of this biological evolution is considered to be just one of the possibilities.

Within the framework of our *global worldviews construction program* at CLEA we have introduced the model of *the layered structure of reality*. This model assumes that the existence of separate bodies of knowledge, i.e. scientific disciplines, concerning parts or fragments of reality has its reasons. The disciplines in the theoretical sciences have not been chosen in an arbitrary way but correspond to a layered organization of reality itself. Reality indeed shows itself to us in the form of layers. The first is a pre-material layer of elementary particles and waves that are the subject matter of quantum physics. This is followed by a material layer, studied by physics and chemistry. The next layers are those of life forms that make up the field of study of biology, and of interacting life forms studied by sociology.

Finally, we have the psycho-cognitive layer, studied by psychology and cognitive science. This layered structure is considered effective and real and not merely a suitable classification. On the other hand, it is clear that the different layers are not separated, but in constant interaction and connected in all kinds of ways, i.e. through contextual, emergent, and downward causation influences. They are *forms of condensation* in reality as an undivided totality. The study of this multi-layered structure of reality, of how the different layers are interconnected, how they emerge one from another, et cetera, is one of the encompassing research themes in CLEA.

The way in which the *psycho-cognitive layer* of reality is considered a part of this layered structure shows that we advocate a naturalized epistemology within this approach. Epistemology is considered to be one of the processes that take place within the psycho-cognitive layer of reality. As such, this layered structure is considered to have grown under the influence of evolution, so that the approach followed at CLEA is compatible with the broad meaning of EE. As we will see in the following, the detection of quantum structures in the psycho-cognitive layer, more specifically in language, makes it possible for us to formulate a criticism of the narrow meaning of EE. The neo-Darwinian view on evolution is in fact a classical view, also if we use the word classical as opposed to quantum, i.e. in the way it is used by physicists. The reason is that the two basic mechanisms of neo-Darwinian evolution, namely *variation* and *selection*, on which the whole view is founded, turn the resulting evolution mechanism into a classical mechanics mechanism. The identification of quantum structures in what we have called the psycho-cognitive layer proves the neo-Darwinian scheme to be too limited for modelling evolution in this layer. To explain in a more concrete way why and how the neo-Darwinian scheme is too limited, we need to introduce new concepts and explain results of foregoing research. We will do this along with an exposition of different but compatible findings of quantum structures in the psycho-cognitive layer in the sections to come.

2. QUANTUM VERSUS CLASSICAL PROBABILITY

To clarify the nature of the shortcoming of the neo-Darwinian scheme for evolution that we intend to reveal, we need to explain the difference between classical probability and quantum probability.

2.1. *The Nature of Classical Probability*

Microscopic physical particles are described by quantum mechanics, which is an indeterministic theory. This means that for a quantum experiment the quantum entity can be prepared in a state such that the outcome of the measurement is not predictable with certainty. Of course, indeterminism of a specific set of experimental setups is not strictly reserved to the micro-world, since indeterminism as a phenomenon related to a specific experiment or set of experiments occurs regularly in the macro-world as well, e.g. the problem of forecasting the weather, which is studied in chaos and complexity theories. Another example is how in the field of population dynamics (Hoppensteadt, 1982) change is described by Markovian chain processes (Markov, 1906; Doob, 1953) using discrete time such that at each moment the state of the system is completely defined by the previous state. Hence classical indeterminism emerges in situations in which *the observer lacks knowledge about the specific state of an underlying deterministic world*. In a classical world, no indeterminism is involved on this deepest level of reality.

2.2. Hidden Variable Theories for Quantum Mechanics

The structure of indeterminism encountered in quantum mechanics is of a completely different and new nature which has, at first sight at least, no counterpart in the macro-world. John von Neumann (von Neumann, 1932) proved that a hypothetical classical underlying theory yielding the probabilities of quantum mechanics as due to a lack of knowledge of the state would never be able to produce the correct numerical probabilities as the ones encountered in quantum mechanics. The hypothetical classical theories considered by von Neumann have been called *hidden variable theories*, because they introduce extra variables such that when all these variables are known every outcome of every experiment can be predicted, and hence the theory is classical deterministic. However, these extra variables are *hidden*, which means that we do lack knowledge on their values, and it is this lack of knowledge that gives rise to probabilities, and hence a classical type of probability.

John Bell remarked that one of the assumptions[2] made by von Neumann does not need to be satisfied for any hidden variable theory, and Bell built on the spot a hidden variable model for a specific quantum system (Bell, 1966). However, Bell's hidden variable model was a very theoretical model, making it impossible to establish the physical meaning of the hidden variable and hence to determine the *wrong* assumption in von Neumann's no-go theorem.

2.3. Classical Versus Quantum Probabilities: The Structural Difference

The different nature of quantum and classical indeterminism is expressed by a deep structural difference of a mathematical nature between the probability

[2] The technical assumption that the expectation value of a linear combination of two observable quantities equals the linear combination of the expectation values.

model of classical mechanics and that of quantum mechanics. Classical probability theory was axiomatised and elaborated into a formal mathematical theory by Kolmogorov in 1933 (Kolmogorov, 1950). The probability model that appears in situations described by classical mechanics—in which the probability is due to a lack of knowledge about the state of the physical entity under consideration—satisfies these axioms of Kolmogorov, and it is called a Kolmogorovian probability model. The probability model that appears in quantum mechanics does not satisfy the axioms of Kolmogorov (Foulis and Randall, 1972; Accardi, 1984; Gudder, 1988; Pitowsky, 1989), such that quantum probability cannot be explained as being due to a lack of knowledge about the state of the system. It is this non-Kolmogorovian nature of the quantum probability model that was already at the core of the proof of John von Neumann's no-go theorem. This was to appear with greater emphasis yet in later corroborations of von Neumann's no-go theorem (Jauch and Piron, 1963; Kochen and Specker, 1967; Gudder, 1968).

2.4. Bell's Inequalities and Kolmogorovian Probability Models

In 1964, Bell analyzed the physical situation presented in the Einstein Podolsky Rosen paper (Einstein et al., 1935) and derived the first formulation of what we now know as *Bell's inequalities* (Bell, 1964). Bell's inequalities are a set of mathematical inequalities formulated by means of expectation values of outcomes of experiments. Bell proves that when there is a *local* hidden variable model for the considered quantum entity, the expectation values predicted for the considered experiments and appearing in Bell's inequalities will be such that the inequalities are *not* violated. By contrast, quantum mechanics predicts that the inequalities *will* be violated. All of the many experiments that were executed yielded highly convincing evidence of Bell's inequalities being violated in the very way predicted by quantum mechanics (Clauser and Shimony, 1978; Aspect, 1999). By introducing the violation versus non-violation of Bell's inequalities principle, Bell offered an operational manner of establishing whether the probability model of a system could be explained from a lack of knowledge about an underlying deterministic world. Pitowsky proved that a probability model is Kolmogorovian if and only if none of the Bell-type inequalities that can be defined by means of expectation values of correlations between different joint measurements of the relevant set of measurements are violated. This means that the detection of a single Bell's inequality being violated suffices to render the collection of probabilities incompatible with a Kolmogorovian structure (Pitowsky, 1989). Before that, Luigi Accardi (Accardi, 1984) had already proved a similar result in a different setting, which was, however, less easy to generalize.

2.5. The Violation of Bell's Inequalities in Different Layers of Reality

A situation giving rise to the violation of Bell's inequalities with measurements on a macroscopic physical entity was considered in Aerts (1982). This model was proven to entail a non-Kolmogorovian probability model, albeit that its non-Kolmogorovian aspect derived from the introduction of a *classical lack of knowledge probability* into the measuring apparatuses used in the example. The contextually driven mechanism identified as causing the probability model to acquire a non-Kolmogorovian structure shows two necessary effects: (1) the interaction with the measurement context changes the state of the system; and (2) there is a lack of knowledge on the way these measurements influence the state of the mechanical system, and hence on the interaction between the measurement context and the system. The existence of a *lack of knowledge on measurements that change the state of the entity under study* is abundantly present in many macroscopic situations (Aerts, 1982, 1986; Czachor, 1992). Much more so than in cases of macroscopic mechanical systems involving measurements that show these two effects, this type of situation will occur naturally with entities that are the common subjects of scientific disciplines in what we know as the human sciences, such as psychology and sociology, since both these effects are typical of the majority of measurements carried out in these fields. This is why it is plausible that non-Kolmogorovian probability structures will be encountered in those layers of reality where the two above effects are present, more specifically in the psycho-cognitive layer of reality.

3. QUANTUM STRUCTURES AND THE HUMAN MIND

In this section we will discuss the different ways in which we have identified quantum-like structures in the psycho-cognitive layer, where the (measurement) context is crucial.

3.1. Modelling Decision Processes

The first situation that we analyzed in this way is that of psychological decision processes, where subjects are influenced by, and form part of their opinions during the testing process (Aerts and Aerts, 1994, 1997; Aerts, 1995). We have set out to prove that the probability model encountered in these situations is non-Kolmogorovian. Let us consider the simple situation of an opinion poll, because here the cause of the non-Kolmogorovian structure can be seen intuitively. Let us suppose the survey contains the following question: "Are you in favour or against the legalization of soft drugs?" The respondents will comprise (1) those that were already in favour before being asked the question; (2) those that were already against before they are asked; and (3) those that were neither in favour nor against before being asked, and make up their opinion in the course of the survey. It is the state of mind of the respondents in the latter group that will be affected by the measurement context (the manner in which the survey is conducted, but also all the details about the environmental situation during the survey), while moreover we lack knowledge on the exact nature of this change of state. These are the two effects that turn the probability model into a non-Kolmogorovian model (Aerts and Aerts, 1994, 1997; Aerts, 1995).

We should point out the following here. Social scientists studying situations that involve opinion polls are of course very much aware of the existence of a subgroup of respondents that have *no opinion* before they are asked to answer the questions. This is usually resolved by including the answer *no opinion* or *don't know*, next to *in favour* and *against*. A quantum model behaves differently. In a quantum model, the introduction of such a third outcome—comparable to the outcome *no opinion*—does not offer an adequate solution. There will still be a group that does not fit in with any of the three alternatives offered, because they do not allow classification along these lines prior to the survey. These respondents did not decide to vote for the third *no opinion* outcome (which would make them have an opinion after all). Their mind is literally *made up* during the survey itself, and hence classifying them as having *no opinion* prior to the survey would be equally erroneous. There is another aspect we wish to point out. Although ad hoc models are made in the field of social sciences for these situations, all these models extract the statistical analysis that they use from *classical statistics*. Classical statistics is a mathematical theory that is built on the mathematical foundation of a Kolmogorovian probability model. Stating that the probability model involved is non-Kolmogorovian is equal to stating that *classical statistics does not apply* in this situation.

3.2. Modelling Concepts

If decision processes entail a quantum-like structure it is plausible that other structures directly connected to the functioning of the human mind equally contain quantum structure. In this respect we were triggered to investigate one of the old and unsolved problems in *concept research*, called the *pet-fish problem*. The pet-fish problem is encountered in concept research when mathematical models for single concepts (pet and fish in this case) are tempted to be combined mathematically to give rise to a model for the combined concept (pet-fish in this case). How to do this is a long standing open problem in concept research. We were able to solve the pet-fish problem by explicitly using a quantum mechanical mathematical representation for concepts (Aerts and Gabora, 2005a, 2005b). Let us sketch in more detail the nature of this solution.

Following the *classical theory* of semantic concepts, there is for each concept a set of defining properties that are necessary and sufficient for category membership. Essential shortcomings of this theory have been identified in many ways (Smith and Medin, 1981; Komatsu, 1992). A fundamental step forward was taken in the seventies, under the influence of the work of Eleanor Rosch and her collaborators at Berkeley. They showed that the *typicality* of exemplars of a concept and the *application values* of properties vary. For example, an *apple*, which is an exemplar of the concept *fruit*, is a more typical exemplar than a *pineapple*, and *juicy* has a higher application value as a property of the concept *fruit* than the property *expensive* has for the concept *fruit*. Rosch formulated the prototype theory: each concept has a prototype and the typicality of an exemplar depends on how similar it is to the prototype (Rosch, 1975, 1978, 1983; Rosch and Mervis, 1975). The breakthrough was that a concept appears as a fuzzy structure, where similarity becomes the measure. A variety of models were proposed, and next to the ones inspired by the prototype idea, the exemplar theories became a second important class. In this category it is not the prototype but salient exemplars that serve as reference; typicality and application value are measured as the distance to these exemplars (Nosofsky, 1988, 1992; Heit and Barsalou, 1996). These theories yield satisfactory predictions in the case of experiments with single concepts for many dependent variables, including typicality ratings[3] and exemplar generation frequencies.[4] However, problems arise when it comes to *combinations of concepts*, for these theories do not allow to account for phenomena such as the so-called *guppy effect*, where guppy is not rated as a good example of *pet* nor of *fish*, but it is rated as a good example of *pet-fish* (Osherson and Smith, 1981). General fuzzy set theory has been tried in vain to deliver a description of the *guppy effect* (Osherson and Smith, 1982; Zadeh, 1982), and this peculiarity can also be understood intuitively: if (1) activation of *pet* causes a small activation of *guppy*, and (2) activation of *fish* causes a small activation

[3] Typicality ratings are ratings made by the subject to whom the experimenter proposes a collection of different exemplars of the same concept, and a collection of different application values of properties of that concept. The ratings can be made in different ways; often a scale from 1 to 7 is used.

[4] Exemplar generation frequencies correspond to tests where subjects are asked to generate exemplars of a specific concept. The frequency of a specific exemplar is considered to be correlated with the typicality of that exemplar.

of *guppy*, how is it that (3) activation of *pet-fish* causes a large activation of *guppy*?

The combination problem is considered so serious that it has been said that not much progress will be possible in the field as long as no light is shed on this problem (Fodor, 1994; Kamp and Partee, 1995; Rips, 1995; Hampton, 1997). As a consequence, existing theories concentrate on attempts to model the combination of at most two concepts (*red apple*, *fake diamond*, *car-seat*, *brain-storm*, *pet-fish*, *etc.*), while the real challenge consists in modelling a sentence, or a set of sentences. Our *quantum mechanical* theory for concepts models an arbitrary combination of concepts, including combinations consisting of more than two concepts, and it also describes the *guppy effect* by making use of the standard quantum mechanical procedure to describe the combinations of quantum entities. We show the quantum effect called entanglement to be at the origin of the guppy effect (Aerts and Gabora, 2005a, 2005b; Gabora and Aerts, 2002a, 2002b). Entanglement is one of the characteristic properties of quantum entities. If two quantum entities are entangled it means that a change of state of one of the quantum entities provokes a corresponding change of state of the other quantum entity. It can be proven that if there would be a physical process carrying this *change of state correlation*, then this physical process is neither a causal nor a local process. In the quantum model for concepts that we worked out, different concepts in a combination (e.g. a sentence) of these concepts are entangled in the sense that if one of the concepts collapses to one of its exemplars (changes its state), also the other concept undergoes a change of state. We refer to Section 4 where we consider the sentence *The pet eats the food*, and where in the process of violating Bell's inequalities we consider different situations where it can be seen how a change of state of *pet* induces a change of state of *food* and vice versa, *pet* and *food* being two entangled concepts within the sentence *The pet eats the food*. The guppy effect is due to the fact that, as a consequence of entanglement, the contextual influence on one of the concepts of a combination of concepts also influences the other concepts in this combination. Literally, if in the combination *pet-fish*, the pet becomes a guppy, then also the fish becomes a guppy, because pet and fish are entangled in the combination *pet-fish*.

3.3. Concepts and Sentences Versus Sources and Data

The main impact of Bell's work was that it shifted the analysis of hidden variables from philosophical speculations to experiment. Bell's inequalities deliver a criterion that allows investigating the probabilistic and *logical* structure of a *source* on the basis of the data it produces. The data are represented by sequences of symbols and are as *ordinary* or *classical* as the characters used to write this article. Bell's inequalities constitute a statistical test investigating correlations between different groups of symbols, and the probability model employed in the analysis is the usual model based on the frequencies of occurrence of certain results. However, and this is one of the ingenious elements of the Bell analysis, certain frequencies are impossible if the source is characterized by a Kolmogorovian model of probability, or—which is roughly equivalent—by a Boolean logic.[5] Again, it should be borne in mind that the goal of the Bell statistical test is to reveal a non-Kolmogorovian *hidden* structure of a source.

The above situation is strikingly similar to that encountered in the investigation of logical structures behind language. A speaker or author is a source, the structures that are the subject of investigation refer to the conceptual level and are as hidden as von Neumann's hidden variables, but the data produced by the source are collections of symbols contained in a computer memory or on a piece of paper. Quantitative linguistics is the field to look for theoretical tools.

When working on the modelling of concepts, and with our approach having allowed us to model an entire sentence as a combination of the concepts contained in this sentence (Aerts and Gabora, 2005a, 2005b), we stumbled rather by accident on articles on the World Wide Web proposing mathematical models for text fragments, more specifically, articles on *Latent Semantic Analysis* (LSA),[6] many of which have been made available through the web by Thomas Landauer's team at the university of Boulder (http://lsa.colorado.edu/). We saw that the mathematical models used were vector space models, which was quite a surprise, since our quantum model is also a vector space model (a Hilbert space, the principal mathematical structure used in quantum mechanics, is a vector space).

Meanwhile, we know that there are different approaches to modelling language on mathematical models, and that most of them use vector spaces as principal mathematical entities. The prominent examples of such approaches are *Latent Semantic Analysis* (LSA) (Deerwester et al., 1990; Landauer et al., 1998), *Hyperspace Analogue to Language* (HAL) (Lund and Burgess, 1996),

[5] Boolean logic is a synonym for classical logic. It is a kind of logic where the propositions form the mathematical structure of a Boolean algebra, carrying the traditional logical operations of conjunction, disjunction, complement and their combinations and formulas.

[6] In LSA, texts are mapped into co-occurrence matrices. Columns and rows of the matrices represent sentences and words, respectively. Scalar products between word-vectors (*i.e.*, rows of text matrices) measure similarity of meaning. LSA recognises that two different words have similar meanings. The procedure is automatic. Computers can *learn* by themselves and pass multiple-choice exams without any real understanding of the test material. Search engines based on LSA can find texts related to a given term even if this term does not occur in the text.

Probabilistic Latent Semantic Analysis (pLSA) (Hofmann, 1999), *Latent Dirichlet Allocation* (Blei et al., 2003) or *Topic Model* (Griffiths and Steyvers, 2004). These methods are based on text co-occurrence matrices and data-analysis techniques employing singular value decomposition.[7] For example, LSA provides a powerful method for determining similarity of meaning of words and passages by analysis of large text corpora. Quite impressive results have been obtained from experiments simulating human performance. For example, LSA-programmed machines proved capable of passing multiple-choice exams such as a Test of English as a Foreign Language (TOEFL)—(after receiving training in general English) (Landauer and Dumais, 1997) and, after learning from an introductory psychology textbook, a final exam for psychology students (Landauer, 2002).

In (Aerts and Czachor, 2004) we explored the structural similarities between these vector space models for language and the Hilbert space model of quantum mechanics. Similarities of mathematical structures between quantum mechanics, and quantum logic and quantum information theory in particular, on the one hand, and those employed in LSA on the other, opened new perspectives for both LSA and the traditional quantum fields of interest. Certain structures quite natural in the quantum domains might help to clarify the difficulties of LSA. One of the first links we noticed was the *bag-of-words problem* of LSA. In LSA a text passage is treated as a *bag of words*, a set where order is irrelevant (Landauer et al., 1998). This is considered to be a serious problem because even on the intuitive level it will be clear that syntax is important to evaluating the meaning of text. The sentences *Mary hits John* and *John hits Mary* cannot be distinguished by LSA. The problem is basically how to *order* words in using vector models. In quantum theories, the problem was solved a long time ago in terms of tensor structures.[8] Quantum experiments confirming the violation of Bell's inequalities in fact aimed to test the presence of tensor structures in the non-Kolmogorovian model of quantum mechanical

[7] Singular value decomposition is a representation of a matrix in the form of a product of three matrices. The middle matrix is diagonal and the elements on the diagonal are termed the singular values. For example, in applications to picture analysis, one cannot practically distinguish between two pictures whose singular values differ by small numbers. Therefore, one of the ways of compressing pictures is by setting small diagonal values to zero and keeping only the values that are sufficiently large. *Sufficient* here is determined by the intended *sharpness* of the picture. The same idea can be applied to any data that is stored as matrices–texts, for example.

[8] Tensor structures are a generalisation of ordinary multiplication that can be applied not only to numbers but also to vectors, matrices, etc. In vector models of probability and logic, the tensor product represents logical conjunction (AND). Tensor structures are all the structures that can be obtained by tensor products of more primitive objects.

probability. In principle, analogous analyses performed on text corpora might reveal non-classical structures in their sources, i.e. the minds of their authors. The idea may seem exotic, but it is not that far from other mathematical techniques employed in quantitative linguistics, and whose roots are in physics. One can mention here the Zipf-Mandelbrot criterion[9] for natural languages and its generalizations resulting from non-extensive thermodynamics[10] and applied to Shakespeare's writings in (Montemurro, 2001) and (Czachor and Naudts, 2002).

Still, the possible influences go in both directions. The tools and experiences developed within LSA might open new perspectives on semantics of quantum programming languages, the languages necessary for programming quantum computers. Moreover, once we realized that tensor structures might form a common basis for quantum information and logic on the one hand, and semantic analysis on the other, we found links to still another field that had been developing independently during the past 15 years or so: distributed representations of cognitive structures in symbolic AI and neural networks.[11] To our surprise, we realized that tensor products were already employed in certain AI investigations (Smolensky, 1990), and that certain alternatives to tensors had been extensively investigated in this context (Plate, 2003). These structures seem unknown to the quantum information community and might prove to be of crucial importance in quantum memory models. We also mention that Widdows and Peters (2003) have investigated connections between LSA and quantum logical structures.

At the moment we are at a crossroad of at least three highly and independently developed fields of knowledge: Quantum information, semantic analysis, and symbolic AI. We are convinced that quantum probabilistic and logical structures will prove essential in the latter two domains, and it is even difficult to imagine in what direction further development will continue.

[9] In a text we can count the number of times a given word occurs, and repeat this procedure for all the words in the text. We can then produce a decreasing curve representing the frequency of occurrence of all the words, starting with the most frequent one. The Zipf-Mandelbrot criterion is a condition on the shape of this curve that allows identifying a text written in a natural language.

[10] Non-extensive thermodynamics is a statistical method of finding probability distributions that are optimal in some sense and characteristic of finite sets of data with long-range correlations. Texts written in natural languages possess such correlations due to syntax, grammar and other linguistic features.

[11] Distributed representations are models that take into account the need for information to be represented in a pattern of activation over a set of neurons, in which each concept is represented by activation over multiple neurons, and each neuron participates in the representation of multiple concepts.

4. THE VIOLATION OF BELL'S INEQUALITIES IN LANGUAGE AND ITS IMPLICATIONS FOR EE

In this section we will present an example of how Bell's inequalities are violated if we apply the model developed for the representation of concepts to language (Aerts and Gabora, 2005a, 2005b). From what we explained in Chapter 2, this proves that language contains genuine quantum structure.

4.1. Concepts as Entities in Different States under Different Contexts

According to Rosch, the typicality of different exemplars of one and the same concept varies (Rosch, 1975, 1978, 1983; Rosch and Mervis, 1975). Subjects rate different typicalities for exemplars of the concept *fruit*, for example, resulting in a classification with decreasing typicality, such as *apple*, *strawberry*, *plum*, *pineapple*, *fig*, *olive*. According to our theory of concepts, *for each exemplar alone* the typicality varies with the context that influences it (Aerts and Gabora, 2005a, 2005b). By analogy, *for each property alone*, the application value varies with the context. We performed an experiment to point out and measure our typicality and application value effect. Participants in the experiment classified exemplars of the concept *pet* under different contexts resulting in typicality ratings given in Table 1.

The context *the pet is chewing a bone* results in a classification with certain typicality ratings, which changes when another context is applied, e.g. the context *the pet is being taught*. It changes again for the context *look what a*

Table 1. Typicality ratings of different exemplars for different contexts

Exemplar	The pet is chewing a bone	The pet is being taught	Look what a pet he has, I knew he was a weird person
rabbit	0.07	2.52	1.77
cat	3.96	4.80	0.94
mouse	0.74	2.27	3.31
bird	0.42	3.06	1.41
parrot	0.53	5.80	1.57
goldfish	0.12	0.69	0.83
hamster	0.85	2.72	1.25
canary	0.26	2.73	0.86
guppy	0.14	0.68	0.83
snake	0.57	0.98	5.64
spider	0.26	0.40	5.96
dog	6.81	6.78	0.91
hedgehog	0.53	0.85	3.48
guinea pig	0.58	2.63	1.31

pet he has, I knew he was a weird person. The effect was also measured for the application value of a property, as can be seen in Table 4 of Aerts and Gabora (2005a, 2005b). The main idea of our concepts theory is to describe this typicality and application value effect by introducing the notion of *state of a concept*, and hence to consider a concept as an entity that can be in different states, such that a context will provoke a change in the state of the concept (Aerts and Gabora, 2005a, 2005b). Concretely, the state of the concept *pet* in the context *the pet is chewing a bone* is different from the state of *pet* in the context *look what kind of pet he has, I knew he was a weird person*. It is this *being in different states* that gives rise to the differences in values for the typicalities of different exemplars and applications of different properties. It is the set of these states and the dynamics of change of state under the influence of context corresponding to experimental data that is modelled by our quantum mechanical formalism in Hilbert space. The problem of the *combination of concepts* is resolved in our theory because in *combination*, the concepts are in different states; for example, in the combination *pet-fish*, the concept *pet* is in a state under the context *the pet is a fish*, while the concept *fish* is in a state under the context *the fish is a pet*. The states of *pet* and *fish* under these contexts have different typicalities, which explains the guppy effect (Aerts and Gabora, 2005a, 2005b).

4.2. Two Pets that Eat their Favourite Food and Violate Bell's Inequalities

Rather than begin by presenting a theoretical exposition of Bell's inequalities, we will introduce the inequalities along with the example discussed, and point out where they are violated. Again, our aim is to prove the presence of quantum structure in language.

Let us assume the following overall context. Amy and Carol, two sisters, both have a pet. Carol has a cat called Felix, and Amy has a dog with the name Roller. The cat and the dog live together with the two sisters, and get along well. They even do not mind to eat together in the same room. But of course, they eat different food, and they both are somewhat special, in that they both have one unique food brand that they prefer above all the rest. For Felix this is *Eukanuba*, a well-known brand of cat food, while for Roller this is *Royal Canin*, a famous brand of dog food. This means that in practice whenever Felix eats, she eats Eukanuba food, and whenever Roller eats, he eats Royal Canin. For a reason that is not completely clear to Amy and Carol they never touch each others' food. One more aspect, Amy and Carol can distinguish very well the food that is served in the room where the eating happens, because Eukanuba and Royal Canin have completely different smells.

Amy and Carol are both playing outside in the garden. The feeding room for the cat and dog is a room that opens onto the garden, but they are playing in a part of the garden where they cannot really see what is happening inside the room. They are, however, aware that one of the pets is being fed by their mom.

We will now take the sentence *The pet eats the food* as our conceptual entity, and denote it by p. The sentence is a *combination of concepts*, i.e. the three concepts *pet*, *eat,* and *food*. The contexts considered are the following:

e: Hey, I think it is Roller who is eating, because I saw him just get in. (pronounced by Amy)
f: I believe that the food that mom served is Eukanuba, because I think I smell it. (pronounced by Carol)
g: One of our pets is eating one of the foods. (thought by both)

The contexts e and f are genuine contexts, i.e. they affect the state of the conceptual entity *The pet eats the food* if applied to it. More specifically, context e affects the concept *pet*, for if we write (e, p) or, in words: *Hey, I think it is Roller who is eating, because I saw him just get in. The pet eats the food*, the concept *pet* of the sentence *The pet eats the food*, is changed into *Roller*, and the sentence becomes *Roller eats the food*. Because of the overall contexts, the concept *food* in the sentence *The pet eats the food* will be affected too. Indeed, because Roller only eats *Royal Canin*, the concept *food* changes to *Royal Canin*, and the sentence *The pet eats the food* changes to *Roller eats Royal Canin*.

In a similar way, we can consider (p, f) or, in words: *The pet eats the food. I believe that the food that mom served is Eukanuba, because I think I smell it*. The context f affects the concept *food* of the sentence *The pet eats the food*, in the sense that *food* changes to *Eukanuba*. Hence the sentence *The pet eats the food* changes to *The pet eats Eukanuba*. Because of the overall context, the concept *pet* is also affected by the context f. The concept *pet* changes to *Felix*, because it is only Felix who eats Eukanuba. Hence the sentence *The pet eats the food* changes to *Felix eats Eukanuba*, under the influence of context f.

Context g is rather a trivial context. Both girls know that *one of the pets is being fed with one of the foods*. This means that it affects neither the concept *pet* nor the concept *food* nor the sentence *the pet eats the food*.

To introduce Bell's inequalities into our discussion, we will have to associate numbers with effects of different contexts. For this purpose, we will consider the effects of the contexts e, f, and g on the sentence p, and define $\mathrm{E}(e, p) = +1$, if it is Roller who is eating, while $\mathrm{E}(e, p) = -1$, if it is Felix who is eating. Furthermore, we define $\mathrm{E}(p, f) = +1$, if the food eaten is Eukanuba, and $\mathrm{E}(p, f) = -1$, if the food eaten is Royal Canin. Similarly, $\mathrm{E}(g, p) = +1$, if one of the foods is eaten by one of the pets, and $\mathrm{E}(g, p) = -1$, if it is not so that one of the foods is eaten by one of the pets. Lastly, $\mathrm{E}(p, g) = +1$, if one of the foods is eaten by one of the pets, and $\mathrm{E}(p, g) = -1$, if it is not so that one of the foods is eaten by one of the pets.

Bell's inequalities come into play when we consider situations that vary with changing pairs of contexts for the sentence *The pet eats the food*, with one of the pairs of contexts affecting the concept *pet* in sentence p, and the other affecting the concept *food* in sentence p. More specifically, it is the four following combinations of pairs of contexts together with sentence p that is considered in Bell's inequalities.

(1) The pair of contexts e and f with p, such that e affects *pet* and f affects *food*. This is represented in symbols as (e, p, f) and in words as *Hey, I think it is Roller who is eating, because I saw him just get in. The pet eats the food. I believe that the food that mom served is Eukanuba, because I think I smell it*.
(2) The pair of contexts e and g with p, such that e affects *pet* and g affects *food*. This is represented in symbols as (e, p, g) and in words as *Hey, I think it is Roller who is eating, because I saw him just get in. The pet eats the food. One of our pets is eating one of the foods*.
(3) The pair of context g and f with p, such that g affects *pet* and f affects *food*. This is represented in symbols as (g, p, f) and in words as *One of our pets is eating one of the foods. The pet eats the food. I believe that the food that mom served is Eukanuba, because I think I smell it*.
(4) The pair of contexts g and g on p, such that g affects *pet* and g affects *food*. This is represented in symbols as (g, p, g) and in words as *One of our pets is eating one of the foods. The pet eats the food. One of our pets is eating one of the foods*.

We will now have to associate numbers with the effects of the contexts on these four combinations. Thus, we define $\mathrm{E}(e, p, f) = +1$ if it is Roller who eats Eukanuba, or if it is Felix who eats Royal Canin. Similarly, $\mathrm{E}(e, p, f) = -1$ if it is Roller who eats Royal Canin or if it is Felix who eats Eukanuba. We define $\mathrm{E}(e, p, g) = +1$ if it is Roller who eats one of the foods, and $\mathrm{E}(e, p, g) = -1$ if it is Felix who eats one of the foods. $\mathrm{E}(g, p, f) = +1$ if it is one of the pets who eats Eukanuba, and $\mathrm{E}(g, p, f) = -1$ if it is one of the pets who eats Royal Canin. Lastly, we have $\mathrm{E}(g, p, g) = +1$ if one of the pets eats one of the foods, and $\mathrm{E}(g, p, g) = -1$ if it is not so that one of the pets eats one of the foods.

Bell's inequalities are the following:

$$|\mathrm{E}(e, p, f) - \mathrm{E}(e, p, g)| + |\mathrm{E}(g, p, f) + \mathrm{E}(g, p, g)| \leq +2$$

Bell's inequalities are violated whenever we have:

$$|E(e, p, f) - E(e, p, g)| + |E(g, p, f) + E(g, p, g)| > +2$$

Let us see what this gives in our situation.

(1) Case (e, p, f)
Amy seems to believe that it is Roller who is eating, but Carol believes that the food is Eukanuba. This means that there are three possibilities. (A) Roller is eating Royal Canin and hence Carol is mistaken about the food. (B) Felix is eating Eukanuba, and hence Amy is mistaken about which pet is eating. (C) Perhaps a new uncommon event occurred, and Roller is eating the cat food. In case A and case B, we have $E(e, p, f) = -1$. In case C, we have $E(e, p, f) = +1$.
(2) Case (e, p, g)
Amy believes that Roller is eating, and since the context is g, there is no reason to doubt her. Certainly one of the pets is eating one of the foods. Hence $E(e, p, g) = +1$
(3) Case (g, p, f)
Carol believes that the food is Eukanuba. In this case too there is no reason to doubt her. Certainly one of the pets is eating one of the foods. Hence $E(g, p, f) = +1$.
(4) Case (g, p, g)
One of the pets is eating one of the foods, hence $E(g, p, g) = +1$.

Let us suppose that it is certain that we are dealing with either case A or case B (thus ruling out the option of Roller's having made a move to eat cat food). In this case we have:

$$\begin{aligned}&|E(e, p, f) - E(e, p, g)| + |E(g, p, f) + E(g, p, g)|\\&\quad = |-1 - 1| + |+1 + 1| = +4\end{aligned}$$

i.e. an extreme violation of Bell's inequalities (indeed, it is the maximum violation).

The more we allow the possibility of case C happening, the less will be the extent of the violation of Bell's inequalities. Yet a real experiment in which the participants are presented with a situation in which the context is explained to them and they are asked to rate their assessments of what is really happening by giving numbers +1 and −1, would still result in a violation of Bell's inequalities, albeit not to the maximum extent of +4. The reason for this is that some of the participants would believe case C to be taking place, rather than suppose that one of the girls is mistaken.

4.3. The Violation of Bell's Inequalities in Language

Before we start to analyze the violation of Bell's inequalities we wish to make the following remark. Suppose that we have the following product equalities:

$$\mathrm{E}(e, p, f) = \mathrm{E}(e, p)\,\mathrm{E}(p, f)$$

$$\mathrm{E}(e, p, g) = \mathrm{E}(e, p)\,\mathrm{E}(p, g)$$

$$\mathrm{E}(g, p, f) = \mathrm{E}(g, p)\,\mathrm{E}(p, f)$$

$$\mathrm{E}(g, p, g) = \mathrm{E}(g, p)\,\mathrm{E}(p, g)$$

In this case we have:

$$\begin{aligned}
&|\mathrm{E}(e, p, f) - \mathrm{E}(e, p, g)| + |\mathrm{E}(g, p, f) + \mathrm{E}(g, p, g)| \\
&= |\mathrm{E}(e, p)\,\mathrm{E}(p, f) - \mathrm{E}(e, p)\,\mathrm{E}(p, g)| + \\
&\quad |\mathrm{E}(g, p)\,\mathrm{E}(p, f) + \mathrm{E}(g, p)\,\mathrm{E}(p, g)| \\
&= |\mathrm{E}(e, p)(\mathrm{E}(p, f) - \mathrm{E}(p, g))| + |\mathrm{E}(g, p)(\mathrm{E}(p, f) + \mathrm{E}(p, g))| \\
&= |\mathrm{E}(e, p)|\,|\mathrm{E}(p, f) - \mathrm{E}(p, g)| + |\mathrm{E}(g, p)|\,|(\mathrm{E}(p, f) + \mathrm{E}(p, g)|
\end{aligned}$$

The fact that $\mathrm{E}(e, p) = +1$ or $\mathrm{E}(e, p) = -1$ implies that $|\mathrm{E}(e, p)| = +1$, and similarly $|\mathrm{E}(g, p)| = +1$, hence:

$$= |\mathrm{E}(p, f) - \mathrm{E}(p, g)| + |\mathrm{E}(p, f) + \mathrm{E}(p, g)|$$

The fact that $\mathrm{E}(p, f) = +1$ or $\mathrm{E}(p, f) = -1$, and $\mathrm{E}(p, g) = +1$ or $\mathrm{E}(p, g) = -1$, yields $|\mathrm{E}(p, f) - \mathrm{E}(p, g)| = 0$ or $|\mathrm{E}(p, f) - \mathrm{E}(p, g)| = +2$, and also $|\mathrm{E}(p, f) + \mathrm{E}(p, g)| = 0$ or $|\mathrm{E}(p, f) + \mathrm{E}(p, g)| = +2$, and clearly if $|\mathrm{E}(p, f) - \mathrm{E}(p, g)| = 0$ then $|\mathrm{E}(p, f) + \mathrm{E}(p, g)| = +2$, while if $|\mathrm{E}(p, f) - \mathrm{E}(p, g)| = +2$ then $|\mathrm{E}(p, f) + \mathrm{E}(p, g)| = 0$, which proves that

$$|\mathrm{E}(p, f) - \mathrm{E}(p, g)| + |\mathrm{E}(p, f) + \mathrm{E}(p, g)| = +2$$

This proves that in this case Bell's inequalities are never violated. This means that any violation of Bell's inequalities requires a violation of at least one of the product equalities. In our example of the two pets eating their favourite food, we have

$$\mathrm{E}(e, p, f) \neq \mathrm{E}(e, p)\,\mathrm{E}(p, f)$$

Indeed, $\mathrm{E}(e, p) = +1$, because Roller is the one who is eating (because of what Amy has seen), and $\mathrm{E}(p, f) = +1$, because it is Eukanuba that is being eaten (because of what Carol smells), but $\mathrm{E}(e, p, f) = -1$, because the overall context makes it very probable that one of the girls is mistaken.

What does all this show?

(1) The origin of the violation is the fact that in the sentence *The pet eats the food* the concepts *pet* and *food* are entangled. More concretely, this means that when the concept *cat* collapses to *Felix*, the concept *food* collapses to *the food that Felix is eating*. We formulated the overall contexts in such a way that this collapse is well defined, so that if *pet* collapses to *Felix*, then *food* collapses to *Eukanuba*. In the overall contexts of the world at large, this entanglement will not be so neatly defined. Even so, the fact is that if *pet* collapses to a specific *pet*, the *food* collapses to a specific *food*, namely the *food* that this specific *pet eats*. This underlying mechanism of entanglement is the mechanism that carries the meaning of the sentence *The pet eats the food*, and it is this which makes this sentence different from *just the bag of words* {pet, eat, food}. That the tensor product can be used to describe this entanglement, exactly as it is done in quantum mechanics, is shown explicitly in (Aerts and Gabora, 2005a, 2005b), where the full quantum mathematical description in Hilbert space is worked out for the sentence *The cat eats the food*.

(2) The violation also requires aspects of language that are not purely logical. It does play a role that we have constructed a situation where the meaning of a particular combination of sentences allows concluding that one of the two girls must be mistaken. This would not be the case if we reduced the situation to a set of logical propositions. In this respect it is worth noting the following: Bell's inequalities are violated because in case (e, p, f) it is plausible that one of the two girls is mistaken, and that it is not Roller who is eating cat food. Of course, also in cases (e, p, g) and (g, p, f) it is quite possible that one of the girls is mistaken. But language functions in such a way that this possibility will be much less taken into account, because there is no reason to believe that one of the girls is mistaken in these situations, whereas there is in situation (e, p, f), which is contradictory, given the assumption that Roller never eats cat food.

(3) We might be tempted to believe, taking into account our remark in (2), that violations of Bell's inequalities in language are strictly linked to contradictory situations. This is not true, however. The contradiction per se is of no importance. What is important is that the effect of context e on sentence p (and more specifically on the concept *pet* as part of sentence p) depends on whether it is context f that affects sentence p (and more specifically the concept *food* as part of sentence p) or context g

that affects sentence p (and more specifically the concept *food* as part of sentence p). If this is the case, we have

$$\mathrm{E}(e, p, f) \neq \mathrm{E}(e, p)\,\mathrm{E}(p, f)$$

with a violation of Bell's inequalities being possible. Our example contains a contradiction (one of the two girls is mistaken) only for the sake of making a clear case without having to perform real experiments on subjects. Although it is obvious that the effect may well be less strong in other contexts, it will still be there, so that we can say that any such other contexts will still give rise to a violation of Bell's inequalities.

We had presented in earlier work a situation where Bell's inequalities are violated in cognition (Aerts et al., 2000). However, the situation considered there introduced conceptual as well as physical contexts, and hence cannot be reduced easily to a purely linguistic situation, as the one considered in the present article.

4.4. The Implications for Evolutionary Epistemology

Section 3 outlined the presence of quantum structures in decision processes and concept structures. Section 4 presented an explicit violation of Bell's inequalities in language, demonstrating the presence of non-Kolmogorovian probability structure in language. Section 2 pointed out that the mathematical models of Markov chains, used to describe the neo-Darwinian mechanism of evolution through variation and selection, is built upon a Kolmogorovian probability model. Technically, this follows from the fact that Markov processes are formulated using a probability structure that is defined on a σ-algebra of events,[12] and this σ-algebra of events makes the probability model Kolmogorovian. Neo-Darwinian evolution is modelled in this way, because this is the natural way to model a mechanism of variation and selection on a *set of actualized entities*, be they phenotypes or genes or other units of evolution. The fact that Bell's inequalities are violated means that the probability structure involved is non-Kolmogorovian, and hence that evolution cannot be modelled using Markov processes. In Aerts et al. (2003), we designed a global mathematical evolution model that incorporates non-Kolmogorovian probabilities. We are currently elaborating this approach by focusing on non-Kolmogorovian models for a replicator dynamics. We are well aware of the highly abstract nature of our criticism of the neo-Darwinian evolution scheme

[12] A σ-algebra is a Boolean algebra that is σ-complete, meaning that denumerable infinite conjunctions and disjunctions of events are allowed, while in a Boolean algebra only finite conjunctions and disjunctions are allowed.

as it stands now. In this sense, it is not obvious whether it can lead to new insights or solutions to some of the well-known problems regarding neo-Darwinian evolution. In view of this, we will outline what we expect might result once we have elaborated much more sophisticated models. Our experience with the effects of quantum models when used in the realm of the micro-world allows us to formulate these expectations in some detail. Of course, the correctness of this speculation depends on how complete the quantum structure of which we have detected aspects is present in the macro-world, more specifically in its psycho-cognitive layer.

A first aspect of *quantum change* that we should mention is the following. There are two types of change: the one is called *collapse*, defined as the change under the influence of a specific and nearby context. The other change is called *dynamical change*, which is defined as a change, not under the influence of a specific nearby context, but rather as the consequence of the global interaction with the rest of the universe. A second aspect to mention is that there are also two types of state with respect to a specific context of the entities involved in evolution. There is a type of state called an *eigenstate*, by which is meant a state where the entity is actualized with respect to this context; more specifically, it is the state the entity is in after it has undergone a collapse type of change under the influence of this context. The second type of state is called a *superposition state*. This is a state that is not actualized with respect to this context, hence it is a potentiality state (Aerts and D'Hooghe, 2005). If it is in such a superposition state, and under the influence of this context, the entity will collapse to one of the eigenstates with a certain probability.

Let us give an example of the type of situation that we think can be described using this formalism. Suppose we consider again the cat food Eukanuba of Section 4.2. Of course, there are many other brands of cat food on the market, for instance Purina, Sophistacat, Bil-Jac, Iams, Whiskas, and Friskies. All of these existing cat food brands are competing on the same North-American market. This is a good example of where in a rather obvious way the neo-Darwinian scheme can be applied. Indeed, some of the brands can be fitter than the others, and if the difference in fitness is too big, the non-fit ones will disappear from the market. All these seven brands are *actualized entities* with respect to the context, i.e. the North-American market. But what about the situation where a new company plans to market a new brand of cat food? Probably there is a particular time-frame in which the new brand exists only in the planning phase: the plans to market the brand are there, and become more and more concrete, but the brand is not yet an *actualized entity* in the market. In our quantum formalism, we will describe this new brand as being in a *superposition state* with respect to the context, which is the North-American market, while an actualized brand is in an *eigenstate* with respect to this context. Of course, in this superposition state (potentiality state), the brand will already be subject to evolution, as the plans evolve. But they evolve in the realms of the interacting minds of the designers, engineers, chemists and marketers that are in the planning of the new brand. The effect of the market on this superposition state is a collapse-type of change; indeed, slowly but definitely the plans for the new brand of cat food change towards an actualization of a new brand on the market. Following its actualization, it will then openly compete with the other brands, which have already been actualized.

Now there are some interesting questions to ask. For example, is there already competition in the superposition phase of evolution? Certainly there is. Indeed, to see this clearly, we just have to consider a situation that is somewhat more complex. Let us suppose that there are two companies considering the introduction of a new brand of cat food. If they know of each other's intentions, there certainly will already be competition in the planning or superposition phase. And, of course, there will also be competition between the not yet actualized brands—the brands in the planning phase, hence in a superposition state—and the already actualized brands, in an eigenstate. It might well be that some of the actualized brands temporarily withdraw to the superposition state again, to allow for plans to be made for adjusting to the newcomers on the market. Our expectation is that all of this possible dynamics will be readily described by a quantum evolution scheme.

The final remark we wish to make concerning EE is the most speculative one, but it is too interesting to be left out. We believe that, with regard to EE, things should be seen in exactly the opposite way. Biological evolution should not be taken as a metaphor for epistemological and conceptual change. It is epistemological and conceptual change that should be taken as a metaphor for biological evolution. We do believe that the change that we readily see happening in front of our eyes in the conceptual, cultural, psychological and social realities around us—let us call this EE-type of evolution—is the more general one, with biological evolution being the more specific one, in some sense a special case of the EE-type evolution. That is why we believe that there are quantum aspects to biological evolution too, although they are much less obvious than the ones we have identified in EE-type of evolution. Let us consider for a moment in this respect one of the biggest problems encountered in biological evolution: the gaps in the fossil records. Now if we were to suppose that biological evolution is quantum-like, we might argue that in this case only actualized life forms, hence life forms in collapsed states with respect to the context—the earth's environment—give rise to fossils, and that a not yet detected undercurrent reality exists, where life forms in superposition states evolve and interact with each other, without ever giving rise to fossils. In this undercurrent of reality, life forms would thus exist in potentiality states, albeit potentiality states that could collapse to an actualized life form, but not necessarily so. These non actualized life-forms evolve under a similar type of evolution as the one that governs epistemological and conceptual entities, which means that they could give rise to new non-actualized life forms, without leaving traces in the context which is the earth's environment. This would explain the gaps in the fossil records and the sudden appearance of new life forms as a natural phenomenon, the equivalent of the sudden appearance of a new brand of cat food on the North-American market, after the brand has evolved in the planning phase within the human minds that are engaged in its planning.

5. CONCLUSION

The neo-Darwinian mechanism of evolution formalized by means of Markov processes on the level of the phenotypes entails an underlying Kolmogorovian probability model. This Kolmogorovian structure of the probability model is not just due to an arbitrary choice for a Markov chain realization of the neo-Darwinian evolution process. The neo-Darwinian accent on *variation* and *selection* as basic mechanisms leads to this Markov formalization, because variation and selection are considered to function on a set of *actualized units of evolution*. We argue in this article that this neo-Darwinian mechanism falls short of describing evolution, because of its limitation to a Markovian process structure, whenever non-Kolmogorovian probability structures are present. We describe the different situations in which we have proved the presence of non-Kolmogorovian probability structure in former research work, more specifically in human decision processes, in how concepts and combinations of concepts are structured. In this article we show the presence of non-Kolmogorovian probability structure in language. Decision processes, concepts and their combinations, and language, are three situations that appertain to the field that is also considered by EE. This means that our finding shows that if EE is interpreted narrowly, and hence attempts to implement the neo-Darwinian mechanism to epistemology, it will stumble upon the problem of the presence of non-Kolmogorovian probability structures in some of the situations of the evolution that it attempts to model. Hence this article is an argumentation for the broad interpretation of EE. More speculatively, we have suggested that it would be preferable to regard epistemological and conceptual evolution (or rather its generalization, which we have called EE-type of evolution—see Section 4.4) as the more general one, and biological evolution as a special case of it, in the same way as for example quantum mechanics is the more general type of mechanics, and classical mechanics is a special case of it. If this line of reasoning is followed with respect to biological evolution, so that also biological evolution would contain quantum aspects (as we believe it does, and we are working on a project to corroborate this), we can sketch a speculative scenario that would provide a natural explanation for the well-known problem in biological evolution of the gap in the fossil records and the sudden appearance of new life forms (Section 4.4).

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