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The Nature of Language

Evolution, Paradigms and Circuits

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The Nature of Language

To my parents,
Charlotte Hillert, née Holland-Cunz
Guido H. J. Hillert

Preface

As an undergraduate student, I studied biology and philosophy at the University of Mainz and felt drawn to topics that relate cognitive phenomena to biological mechanisms. I felt as of today particularly inspired by the work of Derek Bickerton, Noam Chomsky, Charles Darwin, Hoimar von Ditfurth, Paul Feyerabend, Jerry Fodor, Eric Lenneberg, Karl Popper, and William van O. Quine.

After graduate studies at the Goethe University Frankfurt and RWTH Aachen University, I published my first book in German entitled Mental Representations of Word Meanings. Subsequently, I worked as post-doc at the Centre Paul Broca in Paris and EHESS and in Massachusetts at Boston University and MIT. Just before the reunification in Germany, I published my second German book Language Structures and Knowledge Representations. I resumed my work on the science of language at the University of Manchester, Science and Technology in England and at the University of California in San Diego. The autobiographical fragment serves here to acknowledge the institutions that provided support to my work.

The nature of language, aka the neurobiological foundations of language, play a major role in the nature of language. The present book hopes to raise even more attention to this challenging but exciting interdisciplinary research area. Today, new empirical research comes out in large amounts faster than ever. Thus, I must admit that the selected topics are my subjective preference, and I am certain not to have addressed all research relevant to the questions and issues raised. Thus, I did not come close to an exhaustive survey of the literature referring to the nature of language. However, hopefully I presented sufficiently enough to illuminate how these interdisciplinary approaches in this field work and why it is actually a fascinating approach. Keeping this in mind let me introduce "The Nature of Language" with a modified aphorism by Hoimar von Ditfurth (1972, p. 245): *"We are, to put it in this way, in fact the *H. erectus of tomorrow."*[1]

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[1] In: H. v. Ditfurth (1972). *Im Anfang war der Wasserstoff* [German]. Hamburg: Hoffmann und Campe. The original quote used Neanderthals instead of H. erectus.

Introduction

The research area The Nature of Language is continuously growing integrating new methods and knowledge from different fields, and drives into new specialized subfields. The three parts dividing the chapters of this book are considered as significant thematic cornerstones. However, not all important topics can be addressed, but the selection may provide a starting point for further readings beyond the spectrum presented. Thereby, the thematic selection discusses some basic research questions from different angles. They include, but are not limited to:

- How did the human language system evolve?
- What are the neurogentic foundations for language?
- How can we map language processes to neural computations?
- How do we acquire and learn language(s)?

The first part Evolution presents evidence about the human linage and how it relates to the rise of language and cognition. Here, we consider that protomusic may have played a particular role in the evolution of speech and language. We assume that the ability to modulate vocalization has been the primary trigger for the evolution of language. Different stages are suggested from basic cognition to modern language, whereas our early ancestors—in particular H. erectus—might have used forms of communication still reflected in today's languages. In addition, some relevant biochemical mechanisms scaffolding the development, regulation, and maintenance of neural structures associated with language processing, are discussed. The caudate nucleus and basal ganglia, for instance, are significantly involved in speech and can be associated with forkhead-box P2 transcription factors, known as FOXP2. Comparative studies about the communicative behavior of non-human vocalizing species such as birds and whales provide further substantial details about the evolving vocalization mechanisms in different species and how the human language systems might have evolved. A possible evolutionary scenario will be described, which considers a gradual cognitive development from basic to complex communication systems.

The second part Paradigms introduces the concept of the biological disposition of human language. Typically, the language system operates left-sided within fronto-temporal circuits. Particular cortical regions as well as specific dorsal and ventral fiber tracks play a significant role in language processing. We discuss, moreover, our theoretical understanding of how the human language system might be structured. Different cognitive and linguistic approaches and models are presented, which make specific assumptions about the representations and computations of semantic, syntactic, lexical, and figurative information. Building a bridge between theoretical concepts of linguistic cognition and concepts of a neurobiological network or the unification of these approaches are challenging but at the same time intriguing. We introduce and discuss concepts such as natural semantics, binding theory, dependency grammar, artificial neural networks, lexical concepts and constructions, and universal semantic categories. Moreover, we cover the grammar of figurative speech and other idiosyncrasies, which seem to play a particular (or no) role in standard linguistic models.

The third part Circuits emphasizes the neural regions and circuits associated with sentence and/or lexical computations. Different types of electrophysiological (e.g., event-related potentials, magneto-encephalography) and neuroimaging evidence (e.g., structural and functional magnetic resonance imaging) evidence are presented. We discuss in this context the role of the left inferior frontal gyrus and verbal working memory functions in sentence processing and how different data might be accounted for by variance of sentence complexity and other context-dependent factors. Lexical concepts, however, are accessed broadly throughout the cortex. Some lexical concepts are closely associated with sensory-motor representations, others rely more on abstract, conceptual representations. Furthermore, we address the question how the brain computes figurative language as compared to literal language. Neuroimaging data on figurative language indicate that the recruitment of particular cortical regions depends on the linguistic structure of an expression (similar to literal language), but also on the integration of cross-domain knowledge. Particular portions of the parietal lobe, which are part of the mirror neuron system, may have played a significant role in the evolution of concept formation, consciousness, and language.

The final chapters are reserved for issues related to acquisition and (re)learning of one or more languages and how the languages system breaks down in context of a particular medical condition. Here, we discuss three different medical conditions: aphasia, Alzheimer's disease, and autism spectrum disorder. Aphasic syndromes or symptoms are mainly caused by a stroke. Spontaneous post-stroke recovery involves the reorganization of relevant neural circuits and typically the brain shows to some extent unexpected plasticity. In contrast, language degrades along with the progressive decline of cognitive abilities in mild cognitive impairment and Alzheimer's disease. Syntactic and lexical processes are affected as well as working memories functions. Neuroimaging studies let us assume that the brain tries to compensate for degraded processes by recruiting broader and more remote cortical regions. Finally, we discuss autism spectrum disorders, which affect the ability to mentalize and interact socially. Although autism spectrum disorders cannot be considered as a homogenous group, most subjects have in common that they show atypical behavior with respect to figurative and pragmatic aspects of language as well as in tasks involving the theory of mind. The neuroimaging evidence can be considered as inconclusive. A subgroup of children with autism shows an unusual brain growth, which presumably results in atypical connectivity and pruning. Again, neuroimaging data reveal degraded activations in various cortical regions including the prefrontal cortex. The attempt to draw a picture about how our language system works may help to understand and treat these and other neuropsychological conditions involving language and communicative disorders. In sum, the Nature of Language, which is subtitled Evolution, Paradigms, & Circuits, aims to shed light from a variety of different disciplines and approaches on all these questions, statements, and results. The chapters will hopefully inspire to drive and expand the avenue of this fascinating field.

About the Author

Dieter Hillert, born in Germany, is a cognitive scientist and best known for studying language through cognitive, neurobiological and comparative approaches. He holds positions as an Adjunct Professor and Research Scientist, and is affiliated with San Diego State University, University of California, San Diego, and University of Utah. He also works as a science writer on topics related to mind and brain.

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Part I
Evolution

Chapter 1
The Human Lineage

1.1 An Overview

How did language evolve? To approach this obviously mysterious question, we would need to inquire about the evolutionary path of Homo (H.) sapiens—aka – modern humans. The brain of modern humans is equipped with a computational system that provides significant and superior cognitive power. A subsystem of this computational system is the linguistic system. No other biological organism than modern humans has mastered cognitive skills to express inner states, feelings, thoughts, and ideas or to communicate information by using a complex language system, including prosodic, lexical, semantic, and syntactic computations. We do not imply thereby that the ancestors of modern humans did not have language capacities. Instead, we state here, that the biological capacity scaffolding our linguistic system, gradually evolved over millions of years. Thus, for understanding the blueprint of the origin of language it is important to obtain a precise picture about the factors that support those neurobiological processes involved in communicative computations. We refer here with the term "language" to all natural languages, living or dead. The capacity to speak a language is based on universal computations of the human mind and this skill set enables us to create and express infinitely new meanings. What is finite about language are the sets of linguistic rules based on these universal parameters, which in turn are predetermined by species-specific neurobiological dispositions.

Modern humans share a common ancestry with other human primates. Millions of years divide between different species and presumably their evolution is the result of gradual genetic mutations determined by factors we can only speculate about at present. While language is the result of the genotype of H. sapiens, we cannot find evidence for the idea, as we discuss throughout, that this genotype is specifically designed for developing language. Modern humans are equipped with a biological disposition for language (BDL), but it does not result from a single, massive mutation. The human genotype supports specific cognitive properties, which are essential for the acquisition of language as well as for other cognitive capacities. Thus, here we point to a range of different assumptions about events that possibly triggered relatively small mutations in context of natural selection. Many factors

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over time may have shaped the neurobiological processes that allow us exchanging information about the world and how things work, but which can be also used for expressing internal states about emotions, opinions, beliefs, or attitudes. Most of all, language provides social stability among members of a group or population, and it is possible to discuss common goals and intentions.

An influential philosophical view of the twentieth century postulates that only modern humans are born with an innate linguistic universal grammar and implicitly rejects the assumption of a gradual evolution towards a BDL (Chomsky 1995; Bickerton 2009). To abandon the concept of language evolution is an irrational stance and ignores tremendous progress in life-sciences. This creationistic position was (and partly is) particularly popular as it is immune against any empirical data. Otherwise, it reflects the difficulty to develop a plausible cognitive model of primate evolution. For instance, while the age of a primate fossil can be approximately determined with radiometric or incremental readings, it is difficult to understand how these fossils relate to each other and thus how to classify them as part of an evolutionary tree. Even the isolation of mitochondrial (mt)DNA[1] in fossil bones is difficult as DNA degrades over time in dead tissues and bones. In general, it is assumed that fossils older than 40,000 years do not entail DNA. However, the BDL is a result of a long evolutionary process and our cognitive capacity is not as unique as it has been claimed to be in past: each communicative capacity is specific to a particular species, but their interpretations are often anthropomorphized and considered as inferior to the BDL. A better understanding of our linguistic capacities requires considering comparisons to other, non-human communication systems as the BDL is after all the result of natural selection and not of a metaphysical resolution. In this vein, Paul Broca stated once: *"I would rather be a transformed ape than a degenerate son of Adam"* (quoted by Sagan 1979). Before we discuss some possible scenarios that might have triggered and supported the evolution of cognition, let us first review want we know at present about the evolutionary path of mankind.

One of the first ideas about how to examine systematically the relations between single languages and their origin was to describe natural languages in analogy to the assumed evolution of species. August Schleicher (1861), a linguist, used a family tree model that resembled a botanical taxonomy to describe the history of languages in terms of developmental stages such as maturity or decline. At the same time, he was an advocate of a polygenetic account. That is, he assumed that several language groups developed from a speechless ape man (the "Urmensch"), who had ape-like ancestors. Schleicher believed that the large variety of languages, which developed independent from each other, speaks against the idea of a protolanguage, from which modern languages have been derived. In this vein, the zoologist and generalist Ernst Haeckel (1868) argued that different species and races with their different languages are descend from an ape man. Accordingly, many linguists of the late nineteenth and twentieth century believed in a direct relationship between a human race and

[1] mtDNA is in most species, including humans, inherited from the mother. It is located in mitochondria, structures that convert the chemical energy from food into a form that cells can use and can be regarded as the smallest chromosome.