1 Introduction

PETER HAGOORT

Language is not only one of the most complex cognitive functions that we command, it is also the aspect of the mind that makes us uniquely human. Most of our culture clearly depends on the human ability to communicate ideas and construct artifacts with the help of natural language. To a large extent, language is constitutive for human interaction and cooperation. At the same time, the diversity in form and content of existing languages is shaped by the interactional settings in which they are grounded. One of the remarkable features of linguistic phenotypes is that they come in very different forms, at all levels of organization. The sound repertoires of the more than 6,000 languages that are still around today vary widely, as do their grammatical structures, and the meanings that their lexical items code for. For instance, some languages have a sound repertoire of only a dozen phonemes, whereas others have more than 100; some languages have a very elaborate system of morphological markers, whereas others are very limited in their morphological inventory; some languages make semantic distinctions in one domain, others in another domain. Furthermore, sign languages are expressed by movements of hands and face, whereas spoken languages are expressed by movements of the vocal tract. In addition to the variability in the world's languages, there is individual variation in language skills within the population of any given language community. Some people command only a limited vocabulary and simple sentence structures, whereas others are polyglots who can speak multiple languages fluently or do simultaneous translation between languages.

Despite these differences between languages and individual language skills, most children master their mother tongue (spoken or signed) within about the first four years of life and with little or no explicit instruction. They command their native language at a remarkable level of complexity and computational sophistication well before they are capable of lacing their shoes or performing even simple mathematical operations such as addition and subtraction. Moreover, they are internally driven to communicate, exhibiting "proto-conversation" in gesture and vocalization, and passive comprehension well before they can produce any words. This implies that the human brain exhibits a language readiness not found in the brains of other species. What makes for the language readiness of human brains, which genetic instructions contribute to building such a brain, and how does that language capacity build on the other systems of perception, action, memory, and cognitive control?

Insights into the organization of the uniquely human system for language (including the *universality* and *variability* of the human language faculty) will not be gained if we study language at just one level of description and explanation. We will only make progress if we build on the insights from multiple levels of organization. For instance, there are both genetic and cultural contributions to language variability. In addition, we need to combine insights about different cognitive systems that are in continuous interaction with language and that codetermine the structure and content of the utterances that speakers produce and listeners understand. In recent decades, language has been increasingly studied at multiple levels, including neurobiological, psychological, and linguistic levels of description and explanation. The aim of this book is to bring together the knowledge acquired in many different fields (genetic/genomic, neurobiological, psychological, linguistic, computational, and animal research) about the organization of the uniquely human faculty for language.

Ways to investigate this complex cognitive capacity were traditionally restricted to observational and behavioral methods in healthy people and neuropsychological patients with a language disorder. In recent decades, this picture has changed dramatically. Partly due to technological developments and partly as a result of developments in other fields of research, methods to study language and communication have seen a vast increase in number and level of sophistication. Due to the technological progress in computing power, we are now able to build computational models of language processing that are much more advanced than ever before. Thanks to developments in neuroimaging and genetic sequencing, we are able to study the neural basis and the genetic underpinnings of the language-ready brain in an unprecedented manner. These developments, however, come at a price. To be able to appreciate research findings or actively and fruitfully participate in research on human language, one has to

be acutely aware of the developments in the multiple specialized fields that are currently involved in understanding the foundations of human language skills. This is why the need arose for a volume that brings together and summarizes the insights from different angles. The most logical way to do this was to divide up this massive volume into eight parts, each with its own focus and with specialists as section editors. All parts contain state-of-the-art review chapters, and end with a chapter in which the section editors summarize the key issues and point at fruitful future directions for their branch of language research.

Part I on cognitive architectures specifies blueprints for the functional organization of the major language skills, including language comprehension, speaking, and reading. Moreover, it discusses the multimodal nature of human language use and the role of the visual modality in the use of co-speech gestures and sign language.

Part II focuses on learning and developmental trajectories. Children acquire the multiple aspects of language within the first few years of life and beyond, mostly without formal instruction and driven by a need for communication. This part summarizes our current understanding of the many steps and neurocognitive mechanism required to process, encode, and store incoming speech in monolingual and multilingual environments.

Part III discusses the preconditions, evolutionary and otherwise, for advanced communication by means of natural language. Interactional needs and drives might have shaped the coding machinery of a full-fledged language, but they are not dependent on language, and have their own organizational principles, from cognitive as well as neuronal perspectives. The interactional engine is both a precursor of and precondition for a human language system.

Part IV centers on recent developments in modeling language. Enhanced computational power and the availability of large language corpora, as well as the increasing inspiration from knowledge of the brain when modeling data, have together resulted in an enormous boost to attempts at modeling human language processing. We are now at a stage when even the modeling of neurophysiological mechanisms implementing language skills is on the horizon.

Part V discusses the insights from studies that exploit relatively recent ways of measuring brain activity triggered by different forms of cognitive processing. Today a toolkit of cognitive neuroscience methods is available that allows investigations of language in action in the living human brain at an unprecedented scale. Studies using techniques such as functional MRI, electroencephalography/magnetoencephalography, transcranial magnetic stimulation, electrocorticography, and others, enable a linkage between brain and language that goes well beyond the possibilities provided by neuropsychological patients with a lesion in language-relevant brain areas.

Part VI reviews the structural components of the neural infrastructure that makes our brain language-ready. Insights from cyto- and receptor architectonics and from the connectomics of the human brain are discussed. Evidence is provided in favor of important adaptations to the requirements of analyzing and producing speech in areas of auditory and motor cortex, respectively. In addition, neural plasticity in congenitally blind and deaf people offers an inroad into the issue of neuronal degrees of freedom for cognitive computations, in particular for language.

Part VII focuses on the role of genetic factors. The rapid and important developments in molecular methods of the last few decades have made it possible to start deciphering how the genome contributes to building and maintaining a language-ready brain. Genes that have been implicated in developmental forms of language disorders, reading disabilities, and speech motor problems offer novel windows into the biology of language. Investigations of these genes in a range of model systems are deepening our understanding of how different levels of organization (genetic, neurobiological, cognitive) are connected.

Finally, part VIII reviews insights from studying relevant behaviors in nonhuman animals, such as song in birds and vocalizations in primates, to help illuminate possible evolutionary building blocks for speech and language. Although language in the forms that we know seems uniquely human, it is perhaps best conceptualized as a multicomponent system. At least some of the components have analogies and (deep) homologies with behavioral and cognitive features observed in other species. Auditory-guided vocal learning, sequencing abilities, and patterning of sounds are key examples of language-relevant abilities that can be found elsewhere in the animal kingdom. Studies of such traits in animal models, including songbirds and nonhuman primates, might be instructive for the question of how language came into being in our evolutionary history.

Collectively this volume gives a state-of-the-art overview of our current understanding of human language in all its facets. It shows that developing such an understanding depends on interactions between different fields of research and expertise. As for communication between speakers of different languages, cross talk between experts of different fields is not without the

risk of misunderstanding and miscommunication. In these cases, real and substantive interaction happens only with the motivation to listen to each other and to develop a common creole. The purpose of this book is to contribute to the establishment of a common language in interaction between the different fields that are relevant for the scientific endeavor of the language sciences.

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