

## BOOK REVIEW

**The neurobiological basis of language**

These volumes deal with three different aspects of language: its evolution (Lieberman), its acquisition (Tomasello) and its neural organization in the adult (Grodzinsky and Amunts). Readers of all three will thus obtain an up-to-date, rich, picture of contemporary views regarding virtually the entire range of topics in the biology of language. But they will obtain something more: a glimpse of the depth of the disagreements in this field. Unlike many other areas of neuroscience and cognitive neuroscience, there is no agreement about the most basic issue in the area of language and its biological basis—what language is.

It would be difficult to find three books that present more disparate views regarding this fundamental matter. All the authors in these volumes conceive of language as a mental capacity that represents items, events and their relations in symbolic ways that are unique to humans. However, Lieberman, Tomasello, and some contributors to Grodzinsky and Amunts' volume believe that the complexity and diversity of human language is largely a cultural phenomenon, made possible by evolutionary changes in non-linguistic capacities that allow humans to elaborate upon basic capacities for symbolic representation that are shared with non-human species. In contrast, most authors in Grodzinsky and Amunts' book see human language as consisting of abstract representations that are both species- and domain-specific, and that are the result of evolutionary changes that specifically code for the capacity to acquire and utilize these structures. In this review, I will outline the main contribution of each of these volumes and comment on both the material presented in each book as well as the more general issues about which there is disagreement.

Lieberman marshals arguments for an unorthodox view of the evolution of language. In a nutshell, his view is that what evolved to give human language its distinct properties are features of the vocal tract that permit humans to produce the variety of speech sounds we do, coupled with changes in cortical–basal ganglionic structures that permit humans to take advantage of this greater output capacity.

After a brief overview (chapter 1), Lieberman begins his exposition in chapter 2 with an inventory of features of language that are found in non-human species. He reviews both the results of teaching language to non-human species and naturally occurring animal language and communication systems. He concludes that non-human species can

**BROCA'S REGION**

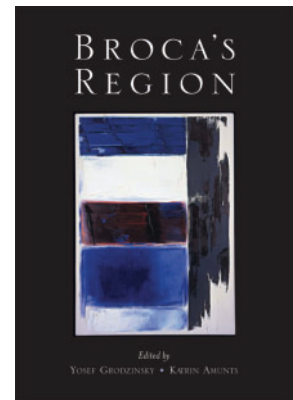
Edited by *Yosef Grodzinsky*  
and *Katrin Amunts* 2006.

Oxford: Oxford University

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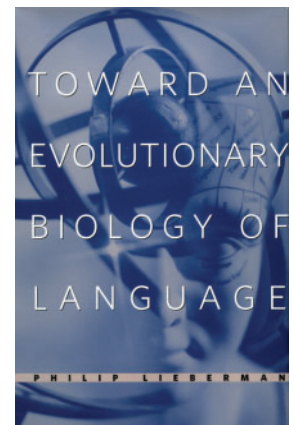
**TOWARDS AND EVOLUTIONARY BIOLOGY OF LANGUAGE**

By *Philip Lieberman* 2006.

Cambridge, MA: Belknap

Price: £32.95/\$49.95/€46.10

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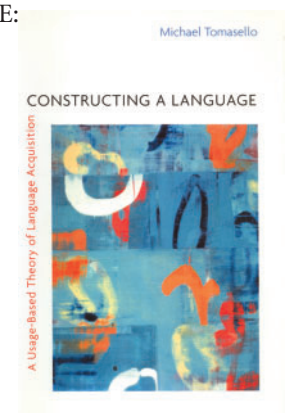
**CONSTRUCTING A LANGUAGE: A USAGE BASED THEORY OF LANGUAGE ACQUISITION**

By *Michael Tomasello* 2005.

Cambridge, MA: Harvard University Press

Price: £13.95/\$19.95/€48.40

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acquire a small set of expressions that have meanings in particular contexts, which he considers similar to words, and very simple processes that relate the ‘meanings’ of these expressions to one another, which he considers to be a simple syntax. Whatever evolved in humans to make for distinctly human language must lie beyond the ability to acquire these forms and meanings.

In chapter 6, Lieberman argues that the critical evolutionary change consisted of the descent of the root of the tongue into the oropharynx. In Lieberman’s view, this seemingly small change in peripheral anatomy has great consequences. It allows for the production of the full range of human speech sounds. A tongue anchored at the end of the horizontal portion of the oral cavity cannot create the range of supralaryngeal vocal tract configurations needed to produce the range of human speech sounds, which requires the descent of the tongue root into the vertical portion of the oropharynx. The effects of the descent of the tongue root are not limited to the ability to produce the inventory of speech sounds of a language, but extend to speech perception as well. Lieberman argues in chapter 3 that the process of perceptual categorization of acoustic features as speech sounds requires the human listener to map acoustic input onto a model of how speech is produced (that is, he subscribes to a version of ‘the motor theory of speech perception’). The simple change of descent of the tongue root into the oropharynx thus both greatly increased the carrying capacity of the efferent communication channel in humans and led to an associated, dependent, increase in the afferent channel.

What was then needed for language to develop was an increase in the neural capacity to utilize this greater channel capacity. Lieberman argues that this was afforded by two genetic effects: increases in the size of the hominid brain related to the ASPM gene and, more importantly, changes in the ability to exploit the increased channel capacity in humans by changes in the FOXP2 gene. The latter gene has been referred to as a (or ‘the’) ‘language gene’ by some researchers, but Lieberman argues that it codes for neuronal features that make for more elaborate and efficient control of sequencing abilities. The loci of such changes are largely subcortical grey nuclei, in particular the basal ganglia and, to a lesser extent, the cerebellum. The critical neural substrate for language is thus a set of cortical–basal ganglionic loops that are involved in functions ranging from motor control (affected in Parkinson’s disease) to task shifting (as manifest by neurovascular responses of the basal ganglia to performing the Wisconsin Card Sorting Task).

In my view, Lieberman fails to make his case. His strongest arguments are those supporting the claim that the descent of the tongue root into the oropharynx differentiates humans and other species and is responsible for the variety of speech sounds found in human languages, a topic on which Lieberman is a recognized expert, but even here the reconstruction of the soft tissues in vocal tracts of early hominids from skeletal remains is necessarily uncertain.

Other sections of the book are less convincing. Lieberman fails to discuss problems with motor theories of speech perception (e.g. the fact that children with developmental speech disturbances can perceive speech sounds). His arguments for the role of subcortical structures in language processing are based on language disturbances found in Parkinson’s patients, functional neuroimaging results in normal subjects, and the effects of hypoxia on language functions. Lieberman does not consider the data critically (e.g. the Parkinson’s and hypoxic patients studied never had metabolic imaging that could establish integrity of cortical structures) and presents results highly selectively (e.g. the functional neuroimaging literature contains hundreds of studies of language effects found only in cortex). His view that the neural structures that are critical for language are mainly subcortical is not supported by the data he cites, or by a very considerable literature that he does not cite.

Tomasello agrees with Lieberman that evolutionary change did not create an ability to acquire abstract representations specific to language but rather led to some other distinctly human capacities that allowed cultural influences to create the complexity of human language. He recognizes the importance of the changes in the vocal tract that Lieberman emphasizes, but emphasizes changes in a variety of cognitive abilities as the crucial evolutionary steps upon which language is built. There are several such cognitive capacities—the ability to share the focus of attention with another person; pattern recognition abilities; and others—but chief among them is the ability of humans to represent others’ minds (to have a ‘theory of mind’).

The heart of Tomasello’s book are its five central chapters, which describe the development of five aspects of language—words, early syntactic constructions, abstract syntactic constructions, nominal and clausal constructions and complex constructions and discourse. These chapters are a wonderful introduction to the field of language acquisition. Tomasello tends to start with phenomena, move to theories of the processes that generate those phenomena, and then critically evaluate those theories. The result could be a dense scientific treatise, impenetrable to all but experts in the field, but it is not: these chapters are so well written that non-specialists will easily follow the presentation. The enormous wealth of data and analysis that is presented is disguised by the limpid and accessible style.

To give just one example, in the chapter on word learning, after reviewing a variety of data regarding the acquisition of words and their meanings, Tomasello discusses three theories that have been advanced regarding how this process takes place. One of these is a reincarnation of associationist learning theory, which will be of interest to readers of *Brain* because it is essentially a version of the view of word learning that is most widely accepted by Neurologists (at least in North America)—the view articulated by Geschwind in his seminal *Brain* papers in 1965 (Geschwind, 1965). The model maintains that children associate novel words with salient aspects of

perceptual experience (in Geschwind's model, these are modality-specific perceptual features). Tomasello first cites experiments that show that children associate a novel word with the salient object in a set of objects whose names the children do not know, but he then goes on to cite studies that show that what makes an object salient is the state of mind of the participants in the experiment, not the physical features of the object *per se*. The critical evidence is that children associate a novel word with the one of four objects that the experimenter had played with and placed next to the other three, but not with the one of four objects that the experimenter appeared to have dropped and that had accidentally rolled next to the other three. The difference in word-object association preferences cannot reflect the perceptual features of the critical object, but must reflect the experimenter's treatment of that item. Time and again, the reader is led along such paths of discovery that first provide a window into the range of phenomena that characterize child language development and then examine the reasons these phenomena occur as they do.

Chapter 8 puts it all together. It first reviews and expands the description of the human cognitive capacities that Tomasello believes account for language acquisition: intention-reading and cultural learning, which provide the impetus to communicate; the capacity to acquire conventional symbols (entrenchment and competition); and the capacity to generalize (schematization and analogy formation leading to syntactic categories, and functionally based distributional analysis leading to the ability to relate linguistic constituents to pragmatic categories). In all areas of language acquisition, Tomasello emphasizes the importance of the ability of the child to appreciate the intentions of his/her interlocutor. He argues against the position taken by Chomsky and others that there are universal structural features that are specific to human language [known as 'Universal Grammar (UG)'] that resulted from evolutionary changes in genes and their neural expression. Like Lieberman, he finds no need to postulate a Universal Grammar of the sort proposed by Chomsky ('Why do we need the phlogiston/ether of universal grammar . . . why not just chuck it?' p. 504). In chapter 8, he systematically reviews and rejects the six major arguments that he says have been made in favor of UG: the existence of 'grammar genes'; linguistic savants; brain localization; a critical period for acquisition; creoles; and the poverty of the stimulus. For Tomasello, there are no general rules that define the structures of even an individual language, let alone all languages; in his view a language is 'a structured inventory of linguistic constructions (p. 295)' whose acquisition requires no special predisposition to process abstract domain-specific structures. Tomasello is one of the major participants in the debate about the existence of UG, and this chapter will give readers an excellent and readable overview of one side of the debate.

In my view, while Tomasello's accounts of the stages of language development are extremely insightful, his basic theoretical position is untenable. The view that languages

are primarily cultural developments cannot explain the fact that there are no significant differences in the complexity of languages with respect to their structures, as is found in domains in which differences across social groups are clearly cultural, such as music or architecture. In addition, the general-purpose pattern recognition and learning mechanisms that Tomasello mentions are insufficient to allow a child to develop the capacity to produce and comprehend the range of structures in an adult language on the basis of the fragmentary examples of a language that s/he is exposed to (the 'poverty of the stimulus' argument). Tomasello denies that adult language is as complex as Chomsky and most contemporary linguists maintain, citing work by linguists such as Croft (2001). In my view, the work Tomasello cites, while extremely interesting and challenging in important ways, does not deal with the issues raised by Chomsky and contemporary linguists and therefore does not explain how the child can acquire the knowledge the adult has about language.

It may be useful for readers to have an idea of what these forms of language are. I cannot do justice to the issues here, but will attempt to illustrate the critical properties of language with an old chestnut of an example. Consider sentence 1:

1. The boat [<sub>RC</sub> that John believed [<sub>SC</sub> Bill painted [<sub>SC</sub>] RC] was red

Sentence 1, which is perfectly acceptable and understandable, contains a relative clause (RC) that itself contains a sentence complement clause (SC), as marked. Sentence 1 can be made arbitrarily (infinitely) long by embedding additional complement clauses within the relative clause:

2. The boat [<sub>RC</sub> that John believed [<sub>SC1</sub> Bill said [<sub>SC2</sub> Mary denied [<sub>SC3</sub> Henry thought . . . Sue painted [<sub>SC3</sub>] SC2] SC1] RC] was red

On the other hand, it is not acceptable to embed even a single relative clause within a noun phrase (NP) that is the object of a relative clause in sentences such as 1. Sentence 3 is essentially identical to sentence 1 in terms of its meaning, but unacceptable because of its form:

3. The boat [<sub>RC1</sub> that John believed [<sub>NP</sub> the claim [<sub>RC2</sub> Bill painted RC2] NP] RC1] was red

These sentences illustrate two fundamental properties of human language: languages consist of an infinite number of structures (Hauser *et al.*, 2002), and there are constraints on the structures that are permitted in any language (Chomsky, 1995) that are not explained by meaning, memory limitations, or other cognitive factors. Though they make considerable progress in accounting for how the child acquires words and constructions, the learning mechanisms described by Tomasello and others do not

explain how the child acquires the potentially infinite number of forms and the constraints on those forms that are found in the language s/he is exposed to. Chomsky and others have thus argued that humans have innate, evolutionarily determined, capacities that allow the child to accomplish this task. In my view, despite many gaps in Chomskian-type models, this argument remains compelling close to 50 years after Chomsky first made it (Chomsky, 1957).

If this view is correct, one way to characterize the task of developing a functional neuroanatomy of language is to relate aspects of these models to neural structures and physiology. Grodzinsky and Amunts' edited volume is a step in this direction. It is a survey of research into Broca's region, the posterior portion of the left inferior frontal gyrus that was the first human brain area to be convincingly associated with language (Broca, 1861). It includes discussions of the neuroanatomy of the region (chapters 1–3) and its role in motor planning (chapters 9–10) and in representing and processing language (chapters 4–8 and 11–16), and concludes with 10 chapters that reproduce classic papers on the region in translation. The editing is excellent, resulting in a homogeneity of chapter length and level of exposition that makes the book as easy to read as possible, given its many quite technical and detailed presentations.

The first three chapters deal with the neuroanatomy of Broca's region, defined as the pars opercularis and triangularis of the left inferior frontal gyrus. Amunts and Zilles (chapter 2) present their important work on the cytoarchitectonics and receptoarchitecture of these areas. Using statistical analyses of laminar changes in the grey level index, they have confirmed the existence of two cytoarchitectonic areas that correspond to Brodmann's areas 44 and 45. The boundaries of these cytoarchitectonic regions vary with respect to macroscopic landmarks. Receptoarchitectonic borders for glutamatergic, muscarinic, cholinergic, adrenergic and serotonergic receptors generally occurred at these cytoarchitectonic boundaries but also identified further subdivisions within each of these areas. Petrides (chapter 3) reviews the data on the histology of areas in the macaque brain that correspond to Brodmann's areas 44 and 45. His conclusion is that macaque has a small area 44 rostral to area 6 and separate from area 45. Both Petrides and Aboitiz and his colleagues (chapter 1) describe the connectivity of these regions. Though some details remain a source of disagreement, it is well established that these areas are divisible into a rostral division that receives afferents primarily from rostral parts of auditory unimodal association cortex (belt and parabelt areas) and inferior parietal cortex and that mainly projects to areas involved in programming eye movements, and a caudal area that receives afferents primarily from caudal parts of auditory belt and parabelt areas and that projects mainly to ventral and orbital prefrontal and agranular frontal cortex.

Most of the book is devoted to work that seeks to identify the function(s) of these areas and that assumes that aspects of Chomsky's theory, or closely related theories of syntactic representations and their processing in language production and comprehension, are correct. Grodzinsky (chapter 6) argues that Broca's region is responsible for operations that relate noun phrases to hypothesized 'underlying' locations in abstract representations of the syntactic structure of a sentence. Drai (chapter 7) seeks to account for the fact that the comprehension performances of patients with Broca's aphasia, whose lesions include Broca's region, are quite variable and do not always show the pattern expected on the basis of Grodzinsky's model of the role of this area in syntactic processing. Friedmann (chapter 5) argues that agrammatic patients' patterns of omission of grammatical endings and function words can be accounted for by postulating that they have a deficit in the ability to construct certain aspects of syntactic trees specified in Chomskian theories. Shapiro and Thompson (chapter 8) present evidence that agrammatic patients can improve if they do exercises that present materials structured along lines suggested by these theories. Friederici (chapter 13) presents a model of the relation of event-related potentials to operations in language comprehension that is heavily influenced by this type of model.

The view of both language and the functions of Broca's region that emerges from this book is, however, not at all a monolithic one. First, even within the chapters that relate this region to structures and operations derived from Chomskian theories, there are differences in the models presented (the exact functions of the region suggested by Friedmann, Grodzinsky and Friederici differ). Second, not all the chapters adopt a view of language as an abstract domain-specific entity. Arbib (chapter 10) is squarely in the Tomasello/Lieberman camp in maintaining that language is largely a cultural development. Arbib has yet another view of the evolutionary change upon which this cultural development is based. In his view, it is an extension of the function of mirror neurons found in the macaque. In the macaque, these neurons fire when the animal either makes or sees certain types of gestures. Arbib argues that this is a rudimentary form of representing the basic semantic information in a sentence—the relation of an actor to an action and its recipient—and that humans have evolved the ability to represent unlimited substitutions of actors and recipients around actions, as opposed to simply being able to substitute the individual with whom one is interacting or oneself as an agent in an action. Other authors also see the functions of Broca's region in language as elaborations of other motor and perceptual functions of this region, in particular the ability to plan and perceive sequences. Third, several chapters (Meyer and Jancke, chapter 14; Hagoort, chapter 15; Fink and his colleagues, chapter 16) make the case that Broca's region is critically involved in cognitive functions other than language.



In my view, this volume is an invaluable source of information about contemporary studies of the neural basis for adult language. Readers interested in contemporary work on the neural basis for language functions would do much better consulting this volume than Lieberman's. That said, the positions presented in this book also need to be critically evaluated. Leaving aside the major disagreements that we have seen pervade this field, there are controversies about the positions taken by the authors of chapters in this book who share the assumption that language consists of abstract domain-specific representations and processes. It is far from clear that the analyses presented in this volume correctly describe the functions of Broca's area, or that these functions are invariantly solely localized in this area as opposed to being multifocally instantiated in the cortex or distributed throughout larger cortical areas, or subject to individual differences in neural realization (see, e.g. Caplan *et al.*, in press; Schlesewsky and Bornkessel, in press; for alternate models). However, as I have said, the chapters in this book are very useful summaries of the views of major researchers in this field, and can serve as sources of hypotheses for other researchers and as an introduction for those interested in recent work in this area.

It seems appropriate for me to end this review with an effort to identify the trends and challenges that I see emerging from these books. First, as I see things, the major challenge remains how to characterize human language—entirely as an 'inventory of constructions' or in part as a set of 'rules' that generate an infinite, though constrained, set of representations. How this question is decided will determine what needs to be learned by the child and probably how it is learned, what is related to the brain, and what human evolution consists of at the functional level. If language does consist in part of abstract, constrained,

rules, a fundamental question is how such rules are represented in neural tissue. The answer to this question will require relating the forms of language and the processes that activate them to neural structures and neurophysiological events, and there is a great deal of work to do in this area.

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