HOW THE HUMAN BRAIN ALLOWS US TO USE LANGAUGE?
THE COGNITIVE STRUCTURE AND MECHANISM TO UNDERSTAND LANGUAGE

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Language and the Brain; A Slim Guide to Neurolinguistics

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The book *Language and the Brain-A Slim Guide to Neurolinguistics* focuses on what is it about the human brain that makes it possible to use language. Language scientists are interested in uncovering the mental computations and representations that make language possible, while neuroscientists focus on how brains are wired to learn and use information. But now scientists don't yet have a comprehensive answer to how this all works. The book discusses the procedures of how the brain transforms waves of sound pressure into meaningful words, how meaning is represented by networks of neurons, and how brain regions work together to receive new words or sentences...

The author of this book Jonathan R. Brennan is an Associate Professor of Linguistics and Psychology at the University of Michigan. He is the Director of the Computational Neurolinguistics Laboratory, which uses theories and models from formal linguistics, cognitive neuroscience, and computational linguistics to study the mental structures and computations used to understand words and sentences. He received the 2019 Early Career Award from the Society for the Neurobiology of Language.

The current review consists of four parts. **Chapter 1 "Introduction" and Chapter 2 "Tool Box"** as **part 1** , lays the foundation for the follow-up. Chapter 1 mainly introduces the brain system in three levels and the linking hypotheses between each level. Besides, the history of studying "language in the brain" is also unfolded a little bit. Chapter 2 mainly introduces the structure of the brain and the tools for investigating the function of the brain. The author firstly distinguishes three levels: 1) the computational goals of a system; 2) the algorithmic steps needed to meet those goals; 3) the implementation in a physical system to carry out those steps. The linking hypotheses capture how possible answers at each of these levels connect. The history to specify these links dates back to 150 years ago, starting with aphasia research or language disorders caused by brain damage. The early aphasia research led to the classical model of language in the left frontal and temporal lobes, which still influences modern theories. In Chapter 2, the author presents the anatomical geography of the brain. And all the prevailing techniques are listed: functional magnetic resonance imaging (fMRI), functional near-infrared imaging (fNIRS), positron emission tomography (PET), electroencephalography (EEG), magnetoencephalography (MEG), electrocorticography (ECoG), transcranial magnetic stimulation (TMS), direct cortical stimulation

(DCS). The operation principle and their suitability for spatial resolution and temporal resolution are illustrated. The applicability is analyzed from the angle of price and ecological validity. But each technique has both pros and cons for making sense of brain structure and function.

Part 2 includes **chapter 3 "Sounds in the brain" and chapter 4 "A neural code for speech"**, explores the process that the sound travelling through the air becomes brain activity. It describes the procedures through three separate transformations. Each takes one step of the procedures from sound to meaning. Acoustic information is represented with a spatial code both at the cochlea and in the primary auditory cortex. Tonotopy is a spatial code for frequency information. The neurons which are adjacent to each other respond to sounds with similar frequencies. The brain may also represent temporal acoustic information in a similar way, called periodotopy. Populations of neurons adjoin the auditory cortex show responses after a speech is heard within 100–200 milliseconds. And the responses show a categorical effect on the different features. The neural representations can encode both the fine structure spectral information that distinguishes different phonemes and the temporal envelope information that encodes syllabic information.

The conversion from acoustic information to a neural representation of sound (neurogram) is carried out within about 100 milliseconds in the primary auditory cortex. To create a phonological sketch, the brain maps from these continuous neural representations of sound, or neurograms, to categorical linguistic units like phonemes within about 100–150 milliseconds in the superior temporal gyrus surrounding the auditory cortex. This mapping (from neurograms to phonemes) is implemented by integrating acoustic information of two temporal windows: a shorter window, around 25 milliseconds, tuned to phonemic features, and a longer window, around 200 milliseconds, tuned to syllabic features. It is worth noting that the auditory cortex shows an asymmetrical response in this process: some studies find that the left hemisphere shows a relatively stronger response to the shorter "phonemic-feature-sized" oscillations, while the right hemisphere shows a stronger response to the longer "syllable-sized" oscillations. At last, the phonological sketch is finally improved by a series of feedback loops between acoustic input and linguistic knowledge, which is called analysis by synthesis. Although this process is assisted by specialized linguistic knowledge, it seems that the process relies on the same basic neural structure used for other kinds of auditory input. Some data indicate that the neural signals illustrate that speech perception is built on the general auditory processing systems that are highly attuned to the specific properties of speech.

Chapter 5 "Activating words" and **chapter 6 "Representing meaning"** as **part 3** deals with the neural foundation of recognizing words and how the brain represents word meaning. Word recognition needs to map a phonological representation to a mental representation of meaning. Phonological representations in the superior temporal gyrus serve to activate lexical items in the posterior middle temporal gyrus. MEG evidence sketches processing stages from acoustic analysis (50–100 milliseconds) to phonological processing in the superior temporal gyrus (100–150 milliseconds), and forwards to lexical access in the posterior middle temporal gyrus (after 250 milliseconds, or 1/4th of a second). The current work is trying to unveil the lexical units that form the bases for recognition. The full decomposition theory and the partial-decomposition theory argue about the input words should be decomposed into minimal morphemes or be approached as whole units before they can be accessed. By this way, it decides the morphological structure will affect relatively early stages of processing or not, about 250 milliseconds before lexical access begins. When the brain implements the task of semantic processing, the distributed network

including the temporal, frontal, and parietal lobes is activated. There are mainly two arguments about semantic processing. The first is about the existence of the semantic hub, and the second is about the concept of embodying. Semantic dementia offers key evidence for the existence of the hub, which is located at the anterior temporal lobes. We know that semantic representations are distributed in the brain, but it is still unknown if those representations are embodied in sensory and action systems. But there seems no relation between the ability to perform actions and the capacity to understand action-related semantics, which doesn't support the embodied hypothesis.

Part 4: chapter 7 "Structure and prediction", chapter 8 "Composing sentences", chapter 9 "Building dependencies" as the main part rises to the sentence level, plus **chapter 10 "Wrapping up"**. The part mainly specifies how the brain makes sense of sentences. To understand a sentence, the constituency, or structural relationships must be identified. And the dependencies between words should also be considered. The brain is an efficient organ, it needs constantly make and check predictions for what comes next in the sentence. Chapter 7 focuses on sentence predictions. There are two familiar syntactic violations in ERP experiments: N400 and P600. Kinds of clues include the information of discourse and the broad social context help to shape predictions on multiple levels of linguistic representations. Except for the predictions that have been made, we also need to consider how the brain might likely deal with new input. Chapter 8 unveils the network of sentence processing. Several different approaches show that sentence processing involves a network that bridges the anterior and posterior temporal lobe (LATL, LPTL) of the left hemisphere, as well as the left inferior frontal gyrus (LIFG). MEG studies reveal increased activation in the LATL within just 200–300 milliseconds after encountering a word, even for simple phrases. The LATL seems to be sensitive to the constituency and the conceptual specificity of a phrase. As for LPTL, it is engaged in processing constituency and argument structure. Chapter 9 focuses particularly on how the brain decodes the dependencies between words. Evidence from aphasia manifests that the left inferior frontal gyrus (LIFG) is engaged in sentence processing, especially complex sentences, including those that entail long-distance dependencies. Another argument is LIFG functioning in domain-specific linguistic representations or domain-general roles in maintaining things of working memory. The evidence from fMRI and the study of primary progressive aphasia appears to support the latter hypothesis - at least some parts of the LIFG play a more domain-general role. But the issue here is whether different sub-parts of the LIFG perform different functions. To handle the question, sub-areas must be teased apart to continue further research, such as the pars triangularis and pars opercularis. In chapter 10, the author checks how well the book achieves the goals that were set out at the beginning, then looks at the current neurolinguistic research from a broad academic background and gives some lessons on where the field may be heading next.

After the introduction of the contents of the book, the advantages and disadvantages also need to be summarized. There are several advantages of the book: 1) The arrangement of the book is very reasonable and systematic with ladders, for example, the geography of the brain and the toolbox at the beginning part make foundations for the later experiments. The content involving the sequence of processing is unfolded from multi-levels and makes readers go from the shallow to the deep. 2) Another merit of the book is the clear structure, which shows in the title and summary part of each chapter. The title of each chapter hit the key points directly, and the relation between the titles of each chapter is very tight and close. There are always leading questions to the next chapter and a summary part at the end of the last chapter so that the reader can easily connect the content and form knowledge networks. The summary part of each chapter lists the main points of

the content in a clear form, which provides great convenience for readers. 3) All aspects are well considered for satisfying the beginners' needs. Both the content and language are at a fundamental level. The examples offered are very classical, and there is not much discussion on different viewpoints. Thereby, conclusions or the results of current research usually give directly to readers. The figures are also arranged very properly. They were put together and matched with clear descriptions of the different parts and how they work, which offers a intuitive and visualized aid.

Despite its benefits, some limitations of this book should also be considered. First, one of the book's most noticeable features is simplification. But some content may need to be fleshed out. The procedures of conducting the empirical neurolinguistic research or guidelines of using different techniques can be regarded as complementary, which offers directions for beginners to begin with. Second, subtitles are needed for the contents. The book has clear titles which reflect the main content of each chapter, but it doesn't have more detailed subtitles. If subtitles are also listed, it will be more efficient for readers to find the correspondent content. Third, the book introduces how the brain processes language and pays more attention to the process of perception. While production is also a significant part of language processing. Thus, the content will be more complete if the production process is added.

Nevertheless, this book is designed to provide a preliminary understanding of neurolinguistics, but there is still some space that can be developed. The latest findings of the research and intriguing detailed work can be extended and summarized if subsequent editions are written in the future.