Why the language-ready brain is so complex

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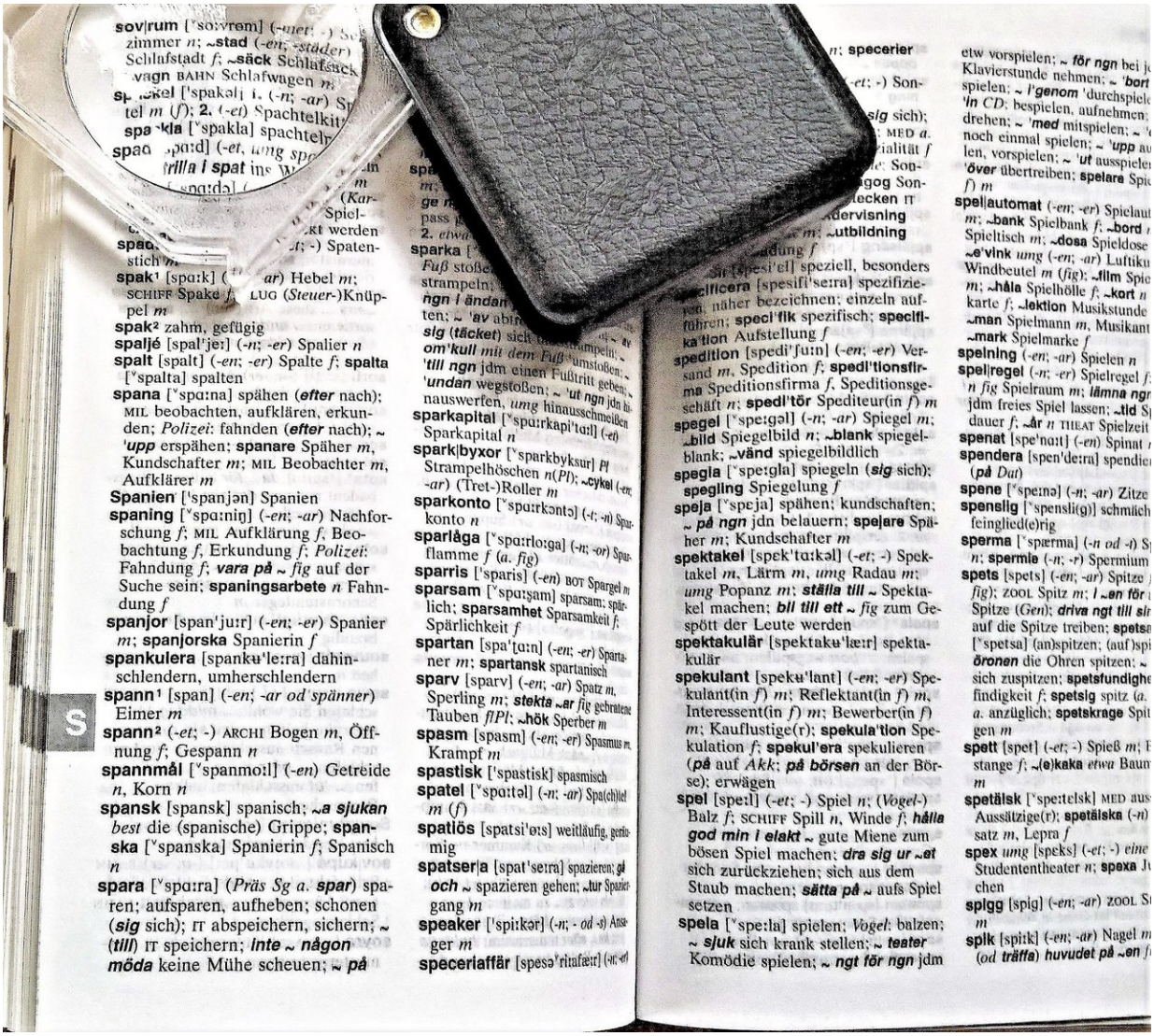

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In a review article published in *Science*, Peter Hagoort, professor of Cognitive Neuroscience at Radboud University and director of the Max Planck Institute for Psycholinguistics, argues for a new model of language, involving the interaction of multiple brain networks. This model is much more complex than the classical neurobiological model of language, which was largely based on single-word processing.

The capacity for language is distinctly human. It allows us to communicate, learn things, create culture, and think better. Because of its complexity, scientists have long struggled to understand the neurobiology of language.

In the classical view, there are two major language areas in the left half of our brain. Broca's area (in the frontal lobe) is responsible for the production of language (speaking and writing), while Wernicke's area (in the temporal lobe) supports the comprehension of language (listening and reading). A large fibre tract (the arcuate fasciculus) connects these two 'perisylvian' areas (around the Sylvian fissure, the split which divides the two lobes).

"The classical view is largely wrong," says Hagoort. Language is infinitely more complex than speaking or understanding single words, which is what the classical model was based on. While words are among the elementary 'building blocks' of language, we also need 'operations' to combine words into structured sentences, such as 'the editor of the newspaper loved the article.' To understand and interpret such an utterance, knowing the speech sounds (or letters) and meaning of the individual words is not enough. For instance, we also need information about the context (who is the speaker?), the intonation (is the tone cynical?), and knowledge of the world (what does an editor do?).

Multiple language areas

In recent years neuroanatomists have discovered that Broca's and Wernicke's regions actually contain multiple neuroanatomical areas. Also, newly discovered language areas extend beyond the classical areas, even into the parietal lobe, with more connections between these areas than previously thought. Moreover, the traditional areas are involved in language comprehension as well as production. Scientists also learned that other regions of the brain are more important for language than once thought, including the right hemisphere and the cerebellum. Interestingly, language areas also turn out to be somewhat variable. For instance, in people who are born blind, language can spread to the occipital lobe (or visual brain).

Our brains process language with astonishing speed and 'immediacy,' in a dynamic network of interacting brain areas. All the relevant information becomes available immediately, as we start combining the meanings of individual words, unifying the different sources of information. To speed up this process, our brain actively predicts what is coming next (for instance, we might expect 'newspaper' to follow 'the editor of the...').

As most utterances are part of a conversation, some information is usually already shared between the speaker and the listener. Speakers make sure that they mark 'new information,' using the order of the words or pitch to focus the listener's attention (after hearing that readers of the newspaper did not like the article, one could say 'the EDITOR of the newspaper loved the article'). Only when relevant 'new' information is unexpected or ungrammatical, people's brains are shown to react. Listeners likely process 'old' information in a 'good-enough' manner, ignoring some of the details, explains Hagoort, which is why they do not seem to notice unexpected 'old' information.

To make matters even more complex, language is often indirect. To know what a speaker really means, listeners need to infer a speaker's

intention. For instance, 'It is hot here' could well be intended as a request to open the window, rather than a statement about the temperature. Neuroimaging studies show that such 'pragmatic' inferences depend on brain areas that are involved in "Theory of Mind," or thinking about other people's beliefs, emotions and desires.

Language is a "complex biocultural hybrid," concludes Hagoort. But what is the essence of human language? Is it syntax, to be found in Broca's area? Hagoort challenges this old notion: "Accounting for the full picture of human language skills is not helped by a distinction between essential and nonessential aspects of speech and language." Instead, the neuroscientist argues for a multiple brain-network view of language, in which some operations might well be shared with other cognitive domains, such as music and arithmetic.

Language being the multi-layered system that it is, no wonder that the language-ready brain is so enormously complex," says Hagoort.

More information: P. Hagoort at Max Planck Institute for Psycholinguistics in Nijmegen, Netherlands el al., "The neurobiology of language beyond single-word processing," *Science* (2019). science.sciencemag.org/cgi/doi … 1126/science.aax0289

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