Revisiting Brain Mechanisms in Language Processing: From the Perspective of Broca's and Wernicke's Area

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Abstract

Due to the great contribution of the classical model to the confirmation of functional specialization of different parts within the brain, Broca's area and Wernicke's area were revisited in the second and third sections respectively. In these two sections, there is a summary of the foundation and location, followed by the function part. At the end of these two sections, the connections between these two areas and other areas of the brain are also mentioned. Then there is a discussion of research on the role of brain mechanisms in language processing by scholars of different eras, including the updated model of ventral and dorsal streams.

Keywords: Broca's Area; Wernicke's Area; Language Processing; Brain Mechanisms; Psycholinguistics;

1. Introduction

The study of the role of brain mechanisms in linguistic function is an ongoing journey, relying heavily on the development of the technological method and biological science over that period. Before the discovery of Broca's area, the majority of academics viewed the cerebral hemisphere as an indivisible unit playing a role in language processing. In the late 19th century, research focused on this topic tended to discuss Broca's and Wernicke's areas separately regarding their functions in language processing. Subsequently, it was revealed that these two sections have intricate functions that cannot be treated solely in terms of how they work in processing language. Nowadays, with the advancement of neuroscience and neuropsychological research, it is claimed that the old "Wernicke-Lichtheim-Geschwind" model, is no longer adequate for researchers' exploration in this field and other models, such as the dual-stream model, need to be taken into consideration.

2. Functions of Broca's area

Broca's region, which has long been associated with language functions, was named after its discoverer, a French surgeon Paul Broca. Generally, this area is located in the left inferior frontal gyrus (IFG) for most people, but there still are some people on the right.

The most important role of this area is associated with language processing, involving speech comprehension and generation. Broca's area of language comprehension has always been overlooked by researchers in the past. However, recent studies showed that the function of this region on language understanding is also significant (e. g. Rogalsky & Hickok, 2011). Explicitly, research using neuroimaging and transcranial magnetic stimulation methods stated that Broca's region has a major role to play in semantic management (Skipper et al., 2007). Speech production includes grammatical and phonological processing (Bulut,2023). During the process of dealing with

grammar, Santi and Grodzinsky 's research (2007) indicated that the particular syntactic function of Broca's area is essential to filler-gap relations. Furthermore, the result of Heim and his colleagues' study (2003) suggested that this area not only plays an important role in speech message detection (e. g. Lee et al., 2012), but also participates in voice information production.

Besides, the physical communication function of Broca's area cannot be ignored, especially in speech-related action discernment and generation (Nishitani et al., 2005). There is mounting evidence shows that Broca's area seems to be performed in the motor domain (Fadiga, Craighero, & DAusilio, 2009). Activation of the region when participants were asked to respond in motion and categorize artificial objects was deemed to prove that (Gerlach, Law, & Paulson, 2002).

In addition to the contribution of Broca's area to linguistic function, increasing evidence suggests that other parts associated with this region may also be engaged in language processing. For example, Bohsali and colleagues' work (2014) suggested that there is a direct connection between Broca's area and the ventral anterior nucleus and the pulvinar, groups of nuclei located in the ventral and upper layers of the thalamus separately, and these regional connection networks are possibly shared language function.

3. Functions of Wernicke's area

Connected to Broca's area by arcuate fasciculus, Wernicke's area was first identified after the discovery of Broca's region over ten years ago by German neurologist, Carl Wernicke. Although there does not exist a clear definition of the exact position of this area (Musiek, 2011), it is widely accepted that Wernicke's area is located in the posterior superior temporal gyrus (STG) within the left hemisphere for the majority (Wernicke, 1874), which is similar to Broca's area.

In contrast to Broca's area, the relation between Wernicke's area and the function of language comprehension has always received a great deal of attention. Utilizing structural magnetic resonance imaging to analyze the relationship between language comprehension data and cortical thickness of Wernicke's area, Jäncke and his colleagues (2021) demonstrated that subjects who have thicker cortex in this region tend to have better competence in language comprehension tasks. More specifically, numerous evidence showed that the role of Wernicke's area is necessary for word recognition (Ardila, Bernal & Rosselli, 2016a). Ardila and his collaborators' other paper (2016b) elaborated on the significance of the Wernicke region in the phonological recognition processing of words. Moreover, studies (Rivera-Urbina, Mendez Joya, Nitsche, & Molero-Chamizo, 2019) conducted recently indicated that this cortical area can also promote the ability of speech memory, for instance, concrete and abstract word acquisition (Kurmakaeva, et al., 2021).

Additionally, the Wernicke area was found to play a more influential role than it was expected before during speech generation, which was claimed by Binder (2015). In addition to the traditional definition of this region, an increasing number of scholars have shown their interest in constructing

different modules to explain the language process. Dewitt and Rauschecker (2013) presented that it seems to be better that interpreting Wernicke's area as two cortical modules: an auditory word-form area (AWFA) in the auditory ventral stream and an ‘‘inner speech area” in the auditory dorsal stream. Mesulam (2013) proposed that the fulfillment of linguistic function (e. g. understanding of concrete words) also needs the participation of the anterior temporal lobe instead of only the posterior of the left hemisphere.

4. Brain theories and language

In the past few decades, many scholars have proposed a variety of approaches to explore the biological basis of language. Some of them are based on cognitive science (e. g. Bever, 1970) and some models are derived from social science theories (e. g. Barkow, Cosmides & Tooby, 1992). Although both camps have gained a good deal of popularity, brain mechanisms will be the theme in this discussion section. Animals and human beings both can communicate with their companions, nevertheless, language is a unique skill for humans. An indispensable reason for this phenomenon tends to be the different brain mechanisms (Caroll, 1986) of humans compared with other species, as discussed above, the specialized region dealing with language issues within human brain.

Research usually starts with the aphasiac who has suffered brain damage in a certain area. Two of the most typical examples are Broca's Aphasia and Wernicke's Aphasia, namely the effect of injury on the two regions discussed above. People with Broca's aphasia usually have difficulties to give grammatical correct speech (Kilborn & Friederici, 1994), but the basic ability of comprehension is still remaining. While the aphasiac of Wernicke's area has semantical problems (Pallickal, 2020). In other words, they cannot speak meaningfully despite fluent speech. Both of these two regions that are necessary for language processing are located within the left hemisphere of the brain, therefore, it seems to be essential to study the effects of cerebral asymmetry on language development. Numerous research is based on it. Caroll (2003) pointed out that the bigger volume of Broca's area in the left hemisphere than it in the right has suggested the correlation between brain structural asymmetry and language competence.

However, with the progress of people's cognition and the deepening of neurology research, a growing body of evidence is proving that the classic model, Broca-Wernicke-Lichtheim-Geschwind, seems to be no longer applicable for lack of sufficient description of language-related neural networks (Tremblay & Dick, 2016). For instance, a study (Bartha-Doering et al., 2018) conducted among thirty-five healthy right-handed children showed that less language lateralization may lead to better performance in language-related tasks. Based on updated knowledge of brain anatomy, the dual-stream model, which involves ventral and dorsal streams, was proposed (Hickok & Poeppel, 2004). Moreover, Nasios and his collaborators (2019) have suggested that there is an increasing need to consider the role of the cerebellum, and the “multiple stream model” of language function.

5. Conclusion

The central theme of this essay is to explore the mechanism of the brain during language processing. In the second part, as the speech motor center, there is detailed proof of the functions of Broca's region, which involves language comprehension, speech production, especially dealing with grammar and sound, and action recognition. Then, the role of language comprehension in particular with word identification of Wernicke's area was discussed. What needs to be noted is that Wernicke's area of speech production is more useful than people used to think. Finally, this essay discussed three models that were proposed by scholars at different times of cognitive and biological development, and the third, the multiple stream model, still needs further study.

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