Psychology & Neuroscience

The Role of Wernicke's Area in Language Comprehension

Alfredo Ardila, Byron Bernal, and Monica Rosselli

Online First Publication, August 8, 2016. http://dx.doi.org/10.1037/pne0000060

Psychology & Neuroscience

1983-3288/16/$12.00 http://dx.doi.org/10.1037/pne0000060

The Role of Wernicke's Area in Language Comprehension

Alfredo Ardila
Florida International University

Byron Bernal
Nicklaus Children's Hospital, Miami, Florida

Monica Rosselli
Florida Atlantic University, Davie

The aphasia literature frequently states that Wernicke's area is responsible for language understanding. The aim of this study was to pinpoint the core function of Wernicke's area. Neuroimaging and clinical data indicate that Wernicke's area participates in phonological and lexical recognition. A much larger brain network is involved in semantic understanding and language comprehension beyond words. We concluded that the "classic" Wernicke's area is the core area that modulates the recognition of individual words.

Keywords: Wernicke's area, aphasia, language understanding, word recognition, temporal lobe

The aphasia literature frequently states that Wernicke's area is responsible for language understanding. For example, Wood (1971) defined Wernicke's area as "a region in the superior convolution of the temporal lobe of the cerebrum identified as the center for understanding speech heard" (p. 23). Nicolosi, Harryman, and Kresheck (2004) referred to Wernicke's area as the "region in the superior convolution of the temporal lobe of the cerebrum which is identified as the center for understanding oral language; corresponds approximately to Brodmann areas 22, 39, and 40" (p. 343). Even general information sources assign the function of speech comprehension to Wernicke's area. The *Encyclopedia Britannica*, for example, defines Wernicke's area as the following:

> [the] region of the brain that contains motor neurons involved in the comprehension of speech. This area was first described in 1874 by German neurologist Carl Wernicke. The Wernicke area is located in the posterior third of the upper temporal convolution of the left hemisphere of the brain. Thus, it lies close to the auditory cortex. This area appears to be uniquely important for the comprehension of speech sounds and is considered to be the receptive language, or language comprehension, centre. (http://www.britannica.com/science/Wernicke-area)

Many other authors and information sources consider Wernicke's area to be involved in *language understanding*. This interpretation of the function of Wernicke's area, however, is not entirely correct. Wernicke's area probably has a more limited function—namely, recognizing phonemes and words (vocabulary). For example, Démonet et al. (1992) used positron emission tomography to analyze brain activation during phonological and lexical semantic processing. The authors found that phonological processing was associated with greater activation of the left superior temporal gyrus, whereas lexical semantic processing was associated with greater activity of the left middle and inferior temporal gyri. These findings are congruent with the aphasia literature, in which pathology of the left superior temporal gyrus (Brodmann area [BA] 22) causes defects in phoneme discrimination, whereas lexical impairments are found in cases of middle temporal gyrus (BA21) damage. Semantic deficits are frequently observed in cases of posterior inferior temporal–occipital (BA37) pathology (e.g., Benson & Ar-

Alfredo Ardila, Department of Communication Sciences and Disorders, Florida International University; Byron Bernal, Radiology Department and Miami Children's Research Institute, Nicklaus Children's Hospital, Miami, Florida; Monica Rosselli, Department of Psychology, Florida Atlantic University, Davie.

Correspondence concerning this article should be addressed to Alfredo Ardila, Department of Communication Sciences and Disorders, Florida International University, 11200 Southwest 8th Street, AHC3-431B, Miami, FL 33199. E-mail: ardilaa@fiu.edu

dila, 1996; Luria, 1976). These observations suggest that Wernicke's area participates in two basic language recognition functions: phoneme discrimination and lexical knowledge. BA37 is not usually included in the classic Wernicke's area. Pathology in this temporal–occipital area results in the highest number of semantic paraphasias that are found across different aphasia syndromes (Ardila & Rosselli, 1993), suggesting significant semantic disturbances.

Mesulam (2001) believed that Wernicke's area is located at the left temporoparietal junction. He further stated:

> Wernicke's area can be said to provide a critical gateway for linking the sensory patterns of words to the distributed associations that encode their meaning. Its dysfunction interferes with the comprehension of words and with the translation of thoughts into words. (p. 426)

In a more recent paper (Mesulam, 2013), he suggested that the anterior temporal lobe of the left hemisphere should also be included in the language network as a third major hub that plays a critical role in language comprehension, particularly the comprehension of words that denote concrete entities. A similar perspective was proposed by Ardila, Bernal, and Rosselli (2016a).

Language understanding unquestionably requires the participation of more extended brain areas. As an illustration, Ferstl, Neumann, Bogler, and von Cramon (2008) performed a meta-analysis of 23 neuroimaging studies on text comprehension that sought to pinpoint the extension of the brain network that is involved in processing language in context. The authors found that, independent of the baseline, the anterior temporal lobes were bilaterally active. The processing of coherent compared with incoherent text also engaged the left dorsomedial prefrontal cortex and posterior cingulate cortex. Right hemisphere activation was seen most notably in the analysis of contrasts that tested specific subprocesses, such as metaphor comprehension. The results generally suggested that when language understanding is processed within a specific context, it is associated with an extensive brain activation circuit that involves not only the left but also the right hemisphere. Evidently, language comprehension within a particular context implies diverse abilities (e.g., abstraction, metaphor understanding, etc.) beyond the purely auditory language understanding of individual words.

Some authors have clearly emphasized this point. For example, Tanner (2007) explicitly emphasized that Wernicke's area is not the center for oral language understanding—it is only an important step in language comprehension. He further stated:

> Auditory comprehension is an ongoing process of receiving environmental information and continuously adjusting the parameters of what is to be perceived and associated. An individual's unique learning and memory experiences play important roles in this process. This process can virtually engage the brain as a whole and the totality of a person's mind. (Tanner, 2007, p. 66)

Wernicke (1970) himself pointed out that the left temporal lobe is involved in recognizing words:

> The whole area of the convolution encircling the Sylvia fissure, in association with the cortex of the insula, serves as [the] speech center. The first frontal gyrus, being motor, is the center for representation of movements, and the first temporal gyrus, being sensory, is the center for word-images. (p. 280)

Binder (2015) stated that although Wernicke's area has been traditionally presumed to be involved in language comprehension, modern imaging and neuropsychological studies indicate that this region plays a much larger role in speech production. Indeed, the posterior perisylvian region, usually referred to as Wernicke's area, does not support the main function that is traditionally ascribed to it (i.e., speech comprehension). According to Binder, language comprehension requires a widely distributed semantic network. This point of view is congruent with the proposals of Ferstl et al. (2008) and Tanner (2007).

Ardila, Bernal, and Rosselli (2016b) suggested that there is a core Wernicke's area that includes not only BA22 and BA21 (as usually suggested) but also BA41 and BA42. This core Wernicke's area participates in the phonological and lexical recognition of words. There is also a fringe or peripheral zone around this core Wernicke's area that is involved in language associations. The fringe or peripheral Wernicke's area corresponds to BA20, BA37, BA38, BA39, and BA40 (i.e., the "extended Wernicke's area"). The classic Wernicke's area (i.e., the "core Wernicke's area") is only involved in the phonological and lexical recognition of words (see Figure 1)—that is, in discriminating the phonemes that are included in words and recognizing the sequence of phonemes corresponding to a word. Semantic recognition requires a more extended network, including at least the adjacent inferior temporal–occipital area, BA37.

DeWitt and Rauschecker (2013) proposed that Wernicke's area may be better construed as two cortical modules (i.e., an auditory word-form area in the auditory ventral stream and an "inner speech area" in the auditory dorsal stream), thus emphasizing the heterogeneity of this language processing area. Dronkers, Redfern, and Knight (2000) proposed that traditional language areas, such as Wernicke's area, may serve somewhat different functions than originally described. They suggested that the analysis of more specific deficits and their anatomical correlates can lead to improvements in the mapping of language functions in the brain.

The transhemispheric contribution of the right hemisphere to language comprehension should also be noted. Prosody importantly contributes to the meaning that is conveyed by the same text. This can vary between languages because some languages more critically depend on this feature, such as tonal languages (e.g., Mandarin, Cantonese, and Vietnamese). In nontonal languages, intonation adds emotional color and meaning to text. With intonation, we can turn a declarative statement into an interrogative statement, convey resentment with sarcasm, or even mean the opposite (i.e., irony). Prosody plays an important role in adding an affective component to sentence comprehension. Interestingly, the same classic dissociation between expressive and receptive functions that exists in the left hemisphere for declarative language has been proposed to exist in the right hemisphere for prosody (Dahan, 2015; Weintraub, Mesulam, & Kramer, 1981). However, a recent study reported rather bilateral hemispheric involvement. Emotional speech comprehension, for example, has been found to involve areas that are adjacent to the superior temporal sulcus bilaterally (Hervé, Razafimandimby, Jobard, & Tzourio-Mazoyer, 2013), although this finding could be partially explained by other variables. Thus, at least one study on prosodic decoding lateralization found that left hemisphere involvement was more precisely associated with the verbal complexity of the prosodic emotional stimuli than with prosody itself (Mitchell & Ross, 2008). Nonetheless, an undeniable fact is the substantive contribution of the right hemisphere to sentence comprehension through prosodic decoding.

Therefore, it is crucial to emphasize that the "classic" Wernicke's area is the core area in the recognition of *individual words*. Ultimately, a much larger brain network is involved in language understanding.

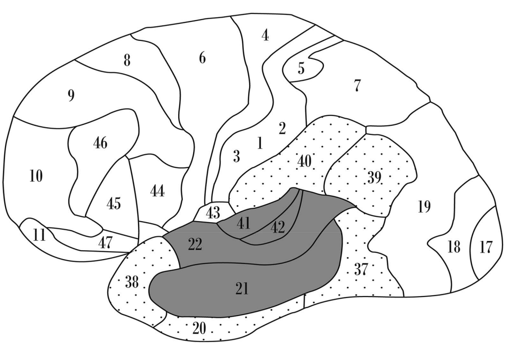

Figure 1. A "core Wernicke's area" is involved in phoneme and word recognition, roughly corresponding to BA41, BA42, BA21, and BA22. An "extended Wernicke's area" or "Wernicke's system" also includes BA20, BA37, BA38, BA39, and BA40; these Brodmann areas (BAs) participate in word associations (i.e., associating words with other information).

References

Ardila, A., Bernal, B., & Rosselli, M. (2016a). How extended is Wernicke's area? Meta-analytic connectivity study of BA20 and integrative proposal. *Neuroscience Journal, 2016,* Article ID 4962562. http://dx.doi.org/10.1155/2016/4962562

Ardila, A., Bernal, B., & Rosselli, M. (2016b). How localized are language brain areas? A review of Brodmann areas involvement in oral language. *Archives of Clinical Neuropsychology, 31,* 112–122. http://dx.doi.org/10.1093/arclin/acv081

Ardila, A., & Rosselli, M. (1993). Language deviations in aphasia: A frequency analysis. *Brain and Language, 44,* 165–180. http://dx.doi.org/10.1006/brln.1993.1011

Benson, D. F., & Ardila, A. (1996). *Aphasia: A clinical perspective*. New York, NY: Oxford University Press.

Binder, J. R. (2015). The Wernicke area: Modern evidence and a reinterpretation. *Neurology, 85,* 2170–2175. http://dx.doi.org/10.1212/WNL.0000000000002219

Dahan, D. (2015). Prosody and language comprehension. *Wiley Interdisciplinary Reviews: Cognitive Science, 6,* 441–452. http://dx.doi.org/10.1002/wcs.1355

Démonet, J. F., Chollet, F., Ramsay, S., Cardebat, D., Nespoulous, J. L., Wise, R., . . . Frackowiak, R. (1992). The anatomy of phonological and semantic processing in normal subjects. *Brain: A Journal of Neurology, 115,* 1753–1768. http://dx.doi.org/10.1093/brain/115.6.1753

DeWitt, I., & Rauschecker, J. P. (2013). Wernicke's area revisited: Parallel streams and word processing. *Brain and Language, 127,* 181–191. http://dx.doi.org/10.1016/j.bandl.2013.09.014

Dronkers, N. F., Redfern, B., & Knight, R. (2000). The neural architecture of language disorders. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (pp. 949–958). Cambridge, MA: MIT Press.

Ferstl, E. C., Neumann, J., Bogler, C., & von Cramon, D. Y. (2008). The extended language network: A meta-analysis of neuroimaging studies on text comprehension. *Human Brain Mapping, 29,* 581–593. http://dx.doi.org/10.1002/hbm.20422

Hervé, P. Y., Razafimandimby, A., Jobard, G., & Tzourio-Mazoyer, N. (2013). A shared neural substrate for mentalizing and the affective component of sentence comprehension. *PloS ONE, 8*(1), e54400.

Luria, A. R. (1976). *Basic problems of neurolinguistics*. New York, NY: De Gruyter Mouton. http://dx.doi.org/10.1515/9783110800159

Mesulam, M. M. (2001). Primary progressive aphasia. *Annals of Neurology, 49,* 425–432. http://dx.doi.org/10.1002/ana.91

Mesulam, M. (2013). Primary progressive aphasia: A dementia of the language network. *Dementia & Neuropsychologia, 7,* 2–9. http://dx.doi.org/10.1590/S1980-57642013DN70100002

Mitchell, R. L., & Ross, E. D. (2008). fMRI evidence for the effect of verbal complexity on lateralisation of the neural response associated with decoding prosodic emotion. *Neuropsychologia, 46,* 2880–2887. http://dx.doi.org/10.1016/j.neuropsychologia.2008.05.024

Nicolosi, L., Harryman, E., & Kresheck, J. (2004). *Terminology of communication disorders: Speech–language–hearing*. Philadelphia, PA: Lippincott Williams & Wilkins.

Tanner, D. C. (2007). A redefining Wernicke's area: Receptive language and discourse semantics. *Journal of Allied Health, 36,* 63–66.

Weintraub, S., Mesulam, M. M., & Kramer, L. (1981). Disturbances in prosody: A right-hemisphere contribution to language. *Archives of Neurology, 38,* 742–744. http://dx.doi.org/10.1001/archneur.1981.00510120042004

Wernicke, C. (1970). The aphasic symptom-complex: A psychological study on an anatomical basis. *Archives of Neurology, 22,* 280–282. http://dx.doi.org/10.1001/archneur.1970.00480210090013

Wood, K. (1971). Terminology and nomenclature. In L. E. Travis (Ed.), *Handbook for speech pathology and audiology* (pp. 3–26). Englewood Cliffs, NJ: Prentice Hall.

Received February 18, 2016
Revision received June 15, 2016
Accepted June 15, 2016 ■