

Response to Willems and Hagoort: an imperfect theory gets you further than random facts

Yosef Grodzinsky¹ and Andrea Santi^{1,2}

¹ Department of Linguistics, McGill University, 1085 Docteur Penfield, Montréal, QC H3A 1A7, Canada

² Department of Neuropsychology, Max Planck Institute for Human Cognitive and Brain Sciences, Stephanstr. 1a 04103 Leipzig, Germany

Our article [1] offers a precise and detailed approach to the functional anatomy of Broca's region and tackles key problems whose solution is a prerequisite for understanding the structure and function of this region (Table 1). We hope to have convinced some readers that empirical testing of current theories of the function(s) of this region is possible, and that among these theories, the syntactic movement account fares best.

Willems and Hagoort make two points on which we agree: (i) that Broca's region is (probably) part of a larger set of networks and (ii) that we should think about how multiple functions are organized within Broca's region. They also aptly observe that we focused on syntax, and argue that there are data indicating that Broca's region also has semantic functions. We would have loved to treat these results in a manner similar to those from syntax, however at this point we see no way of doing so. Although the picture of syntactic processing in Broca's region is relatively clear, studies of 'semantics' do not make for such clarity, and Willems and Hagoort, alas, propose no elucidation.

Although Willems and Hagoort argue for semantic involvement of Broca's region, evoked response potential (ERP) patterns in 'semantic' experiments with patients sharply contradict this claim: deviation from normal is measured in 'patients who have suffered strokes in the left temporal lobe or temporoparietal junction', whereas 'patients with damage restricted to the frontal lobe have typically shown normal semantic context effects' [2]. Moreover, in healthy individuals, even when Broca's region is implicated in semantics, it is one region of many [2,3], as inconsistent results tie an overly rich array of brain loci to 'semantic' tasks. This murky picture stands in stark contrast to the one we drew for syntax. We suspect that, among

other things, this difference stems from the pretheoretical nature of the notions 'meaning' and 'semantics' that some neurolinguists entertain.

Willems and Hagoort indeed harness disparate studies to bolster their view: that is, some experiments they cite presented participants with false and unacceptable sentences (e.g. *Dutch trains are YELLOW/WHITE/SOUR*) [4], whereas others used priming for ambiguous and unambiguous words in unambiguous sentential contexts (e.g. *the shell was fired towards the tank versus her secrets were written in her diary*) [5]. Although both types are dubbed 'semantic', and certainly touch on meaning somehow, no semantic framework we know generalizes over these distinctions. It is no wonder, then, that each of these studies activated multiple, non-overlapping regions, producing a murky anatomical picture that mysteriously contradicts lesion results.

Willems and Hagoort do not try to reconcile these contradictions nor do they propose an alternative to our account. Instead, they allude to an unconstrained notion of a 'network' that offers little help [6]. We restricted ourselves to a single, well-defined function because we felt that an attempt to account for haphazard findings, or to venture even further to see what networks Broca's region is part of, seems overly ambitious at this point. Thus, although Willems and Hagoort rightfully remind us that life does not end with syntax, we find little in their claims that would diminish the force of ours.

Acknowledgements

We are grateful to the following agencies for their continued support: Canada – SSHRC, CRC; USA – NIH grant #DC000494.

References

- Grodzinsky, Y. and Santi, A. (2008) The battle for Broca's region. *Trends Cogn. Sci.* 12, 474–480
- Van Petten, C. and Luka, B.J. (2006) Neural bases of semantic context effects in electromagnetic and hemodynamic studies. *Brain Lang.* 97, 279–293
- Ben-Shachar, M. *et al.* (2004) Neural correlates of syntactic movement: converging evidence from two fMRI experiments. *Neuroimage* 21, 1320–1336
- Rodd, J.M. *et al.* (2005) The neural mechanisms of speech comprehension: fMRI studies of semantic ambiguity. *Cereb. Cortex* 15, 1261–1269
- Hagoort, P. *et al.* (2004) Integration of word meaning and world knowledge in language comprehension. *Science* 304, 438–441
- Eickhoff, S.B. *et al.* A systems perspective on the effective connectivity of overt speech production. *Philos. Trans. R Soc. A.* (in press)

Table 1. Summary of the key questions about Broca's area and our answers

Question	Answer
How can we evaluate functional accounts of Broca's region?	Convergent evidence across methodologies Explicit and constrained theoretical claims Explicit predictions that are borne out
What is the best method for identifying Broca's region anatomically?	Overlap with probability maps of BA44 and BA45
What experimental paradigms are best suited for the study of functional anatomy?	Error analysis in lesion studies Parametric fMRI Designs

Corresponding author: Grodzinsky, Y. (yosef.grodzinsky@mcgill.ca).

1364-6613/\$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tics.2008.12.004 Available online 14 February 2009