What can the brain tell us about *some*?

Einat Shetreet (Havard University & Children's Hospital Boston), Gennaro Chierchia (Havard University), & Nadine Gaab (Havard University & Children's Hospital Boston)

einat.shetreet@childrens.harvard.edu

Scalar implicatures; fMRI; Semantics; Pragmatics; Quantifiers

We often have to make inferences beyond the literal meaning of what we hear. Weak scalar elements like "some" typically give rise to the inference *some but not all* in adults. This inference is part of the enriched meaning of *some* which is assumed to have a single lexical meaning of "all amounts greater than none". The enriched meaning is achieved by the derivation of a scalar implicature. This aspect of language processing has been extensively tested with behavioral methods, showing that adults do indeed derive the implicatures with different types of weak quantifiers and scalar terms (such as *some* and *or*). However, the means by which this derivation occurs are still unclear. Some attribute this process to grammatical-semantic components whereas others suggest a pragmatic mechanism involving theory of mind. The present study utilized fMRI to identify the neural network associated with the enriched meaning of *some* and the derivation of scalar implicatures. Thirteen adults performed a sentence-picture matching task in which they listened to sentences with weak (*some*) or strong (*every*) quantifiers (e.g., "some elephants are dancing") and had to match them to pictures in which all (*all context*), some (*some context*) or none (*none context*) of the individuals performed the relevant action. We focused on the neural processing differences between sentences with weak versus strong quantifiers. We also compared successful implicatures (where sentences with *some* were presented in the *some context*) and failed implicatures (where sentences with *some* were presented with the *all context*). First, we examined brain areas that were more activated for sentences with strong quantifiers compared with sentences with weak quantifiers (*every* > *some*) and no difference was observed. The opposite comparisons which investigated areas that were more activated for weak quantifiers compared to strong quantifiers (*some* > *every*) showed activations in several areas, including the left inferior frontal gyrus (broadmann (BA) area 47). BA 47 was activated for both successful (*some* sentence in *some* context) and failed implicatures (*some* sentences in *all* context). Other areas, including bilateral superior and middle frontal gyri and the anterior cingulate, were activated instead only when implicatures failed. BA 47 has been consistently linked to semantic processing (as shown in meta-analyses and reviews of several neuroimaging studies [1-3]), but not to pragmatic processing (which is linked mainly to the right hemisphere). It has been suggested that this area is involved in integration of semantic information in ways that are different from simple lexical-semantic processes of single word meaning ([4-5]). Thus, our study has three main consequences: (1) the processing of weak quantifiers (where weak means 'weak element of a scale', and possibly also 'non-partitive') generates a greater processing load with respect to that of strong quantifiers. (2) The increased activation in BA 47 for sentences with weak quantifiers vs. strong quantifiers further suggests that the scalar implicature derivation is performed by a semantic, rather than pragmatic, network. (3) The situation in which implicatures fails induce extra cognitive cost. Our results have interesting implications for the debate regarding the nature of the derivation of scalar implicatures.

[1] Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. Cerebral Cortex, 19, 2767-2796.

[2] Bookheimer, S. Y. (2002). Functional MRI of language: new approaches to understanding the cortical organization of semantic processing. Annual Review of Neuroscience, 25,151-188.

[3] Fiez, J. A. (1997). Phonology, semantics and the role of the left inferior prefrontal cortex. Human Brain Mapping, 5, 79-83.

[4] Hagoort, P., Baggio, G., & Willems, R. M. (2009). Semantic unification. In M. S. Gazzaniga (Ed.), The cognitive neurosciences, 4th ed. (pp. 819-836). Cambridge, MA: MIT Press

[5] Sakai, K. L. (2005). Language acquisition and brain development. Science, 310, 815-819.