MEG evidence for distinct sub-operations within semantic composition

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Introduction

The power of language lies in our ability to combine its basic elements to create more complex expressions. A central question in characterizing this combinatory system is whether linguistic composition is a single monolithic operation (e.g. Hagoort, 2011, Hornstein & Pietroski, 2009), or whether composition is accomplished via several distinct sub-operations, as most formal semantic theories would hold. Here we aimed to characterize the potential brain bases of these sub-operations, by employing a broad distinction between two basic composition types standardly assumed in Linguistics: the optional modification of a predicate (modification) and the satisfaction of a predicate's argument position (argument saturation) (Heim & Kratzer, 1998). Due to prior evidence that the left anterior temporal lobe engages in predicate modification (Bemis & Pylkkänen, 2011, Baron & Osherson, 2010, 2011), we hypothesized that this region might specifically subserve composition of this nature. Additionally, we tested four other regions of interest (ROIs) previously hypothesized as combinatory: the left inferior frontal gyrus (LIFG) (Hagoort, 2005), the angular gyrus (AG) (Humphries et al., 2006), the ventromedial prefrontal cortex (vmPFC) (Pylkkänen & McElree, 2006, 2007), as well as the right anterior temporal lobe (RATL). In order to ensure that the results were maximally generalizable, we investigated three different types of predicate modification: the composition of adjectives and nouns (e.g. 'black sweater'), of adverbs and verbs ('runs quickly'), and of adverbs and adjectives ('very funny'), and three types of argument saturation: the composition of verbs ('eats meat'), prepositions ('in Italy'), and determiners ('Bilbo's ring') with their noun arguments.

Design & Method

Target words were visually presented to 14 native English speakers during magnetoencephalography recording sessions, either in combinatory contexts (e.g. "in Italy") or in non-combinatory contexts (target word preceded by an unpronounceable consonant string, e.g. "xq Italy"). To monitor attention, in 20% of trials subjects matched the meaning of a third word to the preceding critical stimulus. Neural activity was measured from the onset of the target word (e.g. "Italy"), such that the activity elicited by combinatory and non-combinatory operations was measured at the same words. The ROI analysis was followed by a full brain analysis.

Results

Non-parametric cluster-based analyses of distributed minimum norm activity at the target words identified a significant interaction at 276-307 ms ($p < 0.05$) in the LATL, where there was more combinatory than non-combinatory activity for predicate modification but not for argument saturation. This result replicated in the full brain analysis. Analyses of sub-conditions suggest this pattern holds across sub-types of predicate modification and of argument saturation. Furthermore, there was some evidence for a more general involvement of the RATL (218-282 ms, $p<0.01$) the vmPFC (371-401 ms, $p<0.05$), and the AG (182-288 ms, $p<0.005$) in composition.

Conclusion

Our results demonstrate a neural distinction between modification and argument saturation. Importantly, this distinction generalized across several instances of the rules. Thus, instead of a uniform combinatory operation, our findings suggest a finer architecture for the composition system of language, establishing a starting point for characterizing the brain bases of its sub-computations.