MODELING NEURAL CORRELATES OF SYNTACTIC STRUCTURE BUILDING

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Using fMRI, we find that the anterior temporal lobe is selectively involved in a computation whose resource consumption profile is isomorphic to that of an incremental phrase-structure parser. This finding extends Brennan et al. (2012) using American English and syntactic analyses grounded in current linguistic theory.

We scanned 11 right handed college-age participants who reported no neurological abnormality. Over headphones, these participants listened to the first chapter of Lewis Carroll's *Alice in Wonderland*, as read by a speaker of American English (12 m 23 s).

We used the text of the story to derive time series predictors, and fit these predictors to preprocessed fMRI data in order to identify regions with correlated activation. One of these predictors simply marks the offset of each spoken word. This predictor localized regions in temporal lobe whose BOLD time series correlates with the rhythm of the spoken narrative. Prior work suggests that the anterior temporal lobe is involved in "basic syntactic processes" (Friederici and Gierhan 2013). We then evaluated the ability of text-based syntactic predictors to account for mean BOLD signal in a 10mm spherical region around these participant-specific peaks.

These text-based predictors were all based on the number of syntactic nodes added to the parse tree word-by-word. Following Van Wagenen et al. (2012), these predictors differed in terms of whether the parsing algorithm was (*T)op-(D)own* or (*B)ottom-(U)p*, and in terms of whether the underlying grammar was based on the (*P)enn Treebank* (Marcus et al., 1993), or (*M)inimalist Grammars* (Stabler 2013). We convolved these node counts with a canonical hemodynamic response function and then orthogonalized them with respect to the word-offset predictor used for localization. We used the resulting time series' to predict BOLD signal in the anterior temporal regions of interest described above.

Using linear mixed effects models, each node count predictor was significant at the $p < 0.05$ level for the left anterior region of interest (BUP β=0.0246 SE=0.0124; TDP β=0.0280 SE=0.0123; BUM β=0.0458 SE=0.1216; TDM β= 0.0559 SE=0.1212). They were not significant in the homologous right hemisphere region. Comparing grammar types and prediction directions, the best fit was achieved using structures generated by Minimalist Grammars with a Top-Down parsing regime (BIC BUP = 9233; TDP = 9231; BUM = 9223; TDM = 9216).

This result represents a kind of match between the sequence of abstract operations taken by an incremental parser and observed BOLD signals in a region that has been assigned to basic syntactic processes.

Brennan, Nir, Hasson, Malach, Heeger and Pylkkänen (2012) Syntactic structure-building in the anterior temporal lobe during natural story listening. *Brain and Language*.
Friederici and Gierhan (2013) The language network. *Current Opinion in Neurobiology*.
Marcus, Marcinkiewicz, and Santorini (1993). Building a large annotated corpus of English: The Penn Treebank. *Computational Linguistics.*
Stabler (2013) Two models of Minimalist, incremental syntactic analysis. *TopICS in Cognitive Science*.
Van Wagenen, Brennan, and Stabler (2012). Quantifying parsing complexity as a function of grammar complexity. Talk presented at the *25th Annual CUNY Conference on Human Sentence Processing*.