The dynamics of Complex Morpholexical Processes, revealed by Searchlight Representational Similarity Analysis of MEG/EEG Data

Li Su[1,2], Elisabeth Fonteneau[1,2], Cai Wingfield[2], and William Marslen-Wilson[1,2]

1. *Department of Experimental Psychology, University of Cambridge, UK*
2. *MRC Cognition and Brain Science Unit, 15 Chaucer Road, Cambridge, UK*

Introduction Although the neural basis of speech comprehension has been a growing focus for neuroimaging research, detailed neural models of morpho-lexical processing are notably absent. Here we explore how the underlying properties of lexical constituents are computed in neural networks situated in bilateral fronto-temporal brain regions that have been previously associated with speech comprehension (c.f. Bozic, M. et al. 2010 and Marslen-Wilson et al. 2007). In particular, we target on the critical process occurs at around Inflectional Recognition Point (IRP).

Methods A novel method that reveals the fine grained structure of neural computation (with centimetre and millisecond precision) has been developed based on the Representational Similarity Analysis (RSA) of MEG/EEG data in source space using searchlight techniques. RSA is a variation of Multivariate Pattern Analysis (MVPA), which has been successfully applied to fMRI data (Haxby et al., 2001; Kriegeskorte et al., 2006; Haynes and Rees, 2006). RSA is based on the pattern-information that is naturally embedded in multi-channel recording of neural activations.

17 healthy, right-handed native English speakers have participated in the experiment. Combined MEG and EEG data was collected at MRC's Cognition and Brain Sciences Unit using a 306-channel Vectorview MEG and 70-channel EEG system. We pre-processed the data with minimum-norm estimation (MNE; Hämäläinen and Ilmoniemi, 1994) with three-compartment boundary-element forward model from structural MRI (3T), and then computed a distributed-source solution combining both MEG and EEG scalp information.

After pre-processing, we computed similarity structures that summaries the dynamic patterns of neural activation over space and time. The primary data type that encodes such similarity structure is the representational dissimilarity matrix (RDM). Each entry in an RDM is the correlation-distance between activation patterns elicited by a pair of experimental conditions, e.g. with and without inflection. We then drew neuroscientific inferences from a second level of analysis that compares data RDMs to theoretical models, which were characterized by a set of theoretical model RDMs. These models describe different dimensions of lexical complexity, and form a hierarchical structure. At this step, a spatio-temporal searchlight algorithm combined with nonparametric statistics looks for neuro-computational signatures that are correlated with these models.

Results A bilateral neural network including both frontal and temporal lobes has been indentified using this method. In particular, we are able to separate different neural representations across space and time within the above neural network. Each representation is associated with information embedded in a particular aspect of morpholexical processes such as the processing of inflectional morphemes.

Conclusions Our results revealed a dynamic and holistic view of morpho-lexical processing and potentially provide a system level account of neural processing for speech comprehension. In contrast with reductionism, the searchlight RSA combined with time resolved neuroimaging techniques such as MEG/EEG rigorously integrates multiple neuro-psychological components and result in a relatively complete picture of the large-scale interaction in the brain.