Workshop on Predictive Processing

Title of the symposium:

Predictive and non-predictive computations for Bayesian inference in speech and language

Organizers:

Matt Davis, MRC-CBU, Cambridge, UK
Gina Kuperberg, Tufts/MGH, Boston, MA, USA

Abstract:

There is abundant evidence that human speech and language processing adheres to the principles of optimal Bayesian Inference; listeners compute the most probable interpretation of degraded or ambiguous words in speech. However, the neural implementation of these Bayesian computations, and the role of predictive mechanisms in these processes remains unspecified.

Máté Lengyel will begin by providing an overview of different computational mechanisms that may implement Bayesian inference in the brain. While "predictive coding" is a common algorithmic/representational motif this may serve several different computational goals of which Bayesian inference is but one. Conversely, while Bayesian inference can utilise predictive coding, it can also be realised by a variety of other representations. Evidence of differential brain responses to predicted and unpredicted stimuli may not distinguish between these different neural algorithms. Specifically, he will focus on a recent alternative proposal for the neural basis of Bayesian inference: sampling-based direct variable coding, according to which probabilistic predictions (and not prediction errors) are encoded in the variability of neural responses. He will show how such sampling-based inference, without an explicit representation of prediction errors, can account for key aspects of cortical dynamics – some of which were commonly taken to be signatures of predictive coding.

Matt Davis will then present neural data from studies of speech perception that potentially differentiate between predictive coding and alternative, sharpening/interactive activation implementations of Bayesian inference. This work involves assessing the perceptual and neural impact of informative and mismatching written text (prior knowledge) that precedes degraded speech. Multi-voxel fMRI response patterns and MEG responses in the superior temporal gyrus (STG) show interactions between prior knowledge and speech clarity in line with Prediction error representations. Furthermore, multi-voxel fMRI patterns represent mismatching segments when listeners reject partially-matching prior knowledge, and fail to signal matching segments when listeners misperceive degraded speech as matching expectations. Both these observations are contra sharpening mechanisms but consistent with computational simulations in which the STG represents the difference between heard and expected speech sounds (neural computations of prediction error).

In the third talk, Gina Kuperberg will discuss what various ERP, MEG and fMRI measures can tell us about the computational nature and consequences of lexico-semantic prediction during word-by-word sentence and discourse comprehension. She will first present the results of a study that combines MEG with Representational Similarity Analysis to show that the pre-activation of semantically distinct words can be detected as unique spatial and temporal patterns of neural activity, in the absence of new bottom-up input. She will then discuss how the brain responds to new semantic inputs in the light of prior semantic predictions, focusing on time-locked neural responses, evoked between 300-500ms (the N400) after the onset of new inputs, which can be localized to the left lateral and medial temporal cortex. Rather than simply reflecting the semantic features encoded within the bottom-up input, the N400 response is highly sensitive to the semantic probability of that input, given the context. Importantly, it is just as large to unpredicted words encountered in non-constraining contexts (when the prior is highly uncertain), as to equally unpredicted words that violate strong predictions (when the prior is highly certain). She will suggest that the N400 may reflect the shift in belief from a prior to a posterior distribution, although the precise level of representation at which this shift occurs remains unclear. One possibility is that it primarily reflects the shift in belief at the level of semantic features. Another possibility is that it reflects the shift at the level of the latent cause that generates these semantic features – the underlying event the communicator intended to convey. She will discuss how it may be possible to disentangle these accounts.

Title talk 1: Bayesian inference in the brain: predictive coding vs. sampling-based representations

Authors talk 1: Máté Lengyel, Computational and Biological Learning Lab
Department of Engineering, University of Cambridge, Cambridge, UK

Title talk 2: Predicting and perceiving degraded speech

Authors talk 2: Matt Davis, MRC Cognition and Brain Sciences Unit
University of Cambridge, Cambridge, UK

Title talk 3: Lexico-semantic predictions during sentence and discourse comprehension

Authors talk 3: Gina Kuperberg, Dept. of Psychology, Tufts University, and
Dept. of Psychiatry, Massachusetts General Hospital, Boston, MA, USA