Integration and Prediction in Language

Organizer: Ole Jensen and Lin Wang

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Neural Mechanisms of Language Integration and Prediction

Language comprehension relies on several brain regions interacting on a very fast time-scale in order to support the required cognitive operations. Two important processes that contribute to successful language processing are integration and prediction. Integration refers to the combination of lexical, syntactic, semantic and contextual information, whereas prediction refers to an anticipatory pre-activation of words amongst others based on contextual information. Integration serves as a basis for prediction and in turn prediction facilitates the integration of upcoming words. In order to understand the brain mechanisms involved in language processing, it is important to characterize neural activities related to integration and prediction in the brain, both in time and in space. In this symposium, speakers will present human electrophysiological data including MEG to better understand the network dynamics underlying integration and prediction in language processing.

Speakers:

- **Liina Pylkkänen** (New York Univ., USA)
  "The brain's combinatory network as revealed by MEG"

  Although our brains' ability to build complex meanings from simpler representations is fundamental to all of language, our understanding of the neurobiology of meaning composition is still grossly generic. To characterize the neural bases of semantic composition more mechanistically, a cognitive model is needed to define the space of possibilities. Our research departs from most mainstream cognitive neuroscience on semantics by taking the results of formal semantics within theoretical linguistics as the model that fundamentally guides the experimentation. Our MEG research implicates a shared combinatory network between comprehension and production comprising at least of the left anterior temporal lobe and the ventromedial prefrontal cortex. In contrast to hypotheses arising from hemodynamic literature, our MEG studies have not implicated the angular gyrus (AG) or the left inferior frontal gyrus (LIFG) as systematically sensitive to basic composition; instead, our data suggest a role in relational processing for the AG and in retrieval operations for the LIFG. To conclude, I will sketch a spatio-temporal progression of the MEG correlates of various stages of language processing as implicated by our group's work over the last 15 years, from the prediction of visual word forms to higher level integrative processes and reference resolution.

- **Ole Jensen** (Donders Institute, The Netherlands)
  "Alpha oscillations in the language network reflect prediction during reading"

  It has been demonstrated that readers and listeners actively predict upcoming words during language processing. However, it remains unclear which neural activity reflects prediction. In this talk, I will present our recent MEG data on the neural oscillatory activities associated with language prediction. We found strong alpha power suppression preceding the highly expected words were presented in both language network (left inferior frontal cortex, left superior and middle temporal region, visual word form area) as well as subcortical regions (left hippocampus and right cerebellum). In addition, there was strong alpha phase consistency in the left inferior frontal cortex and the right cerebellum when there was strong prediction of upcoming words. The involvement of the VWFA suggests that participants made predictions at the word form level. Furthermore, the left frontal, temporal language areas as well as left hippocampus and right cerebellum are likely to participate in the generations of these predictions. In addition, our study

extends previous research on the function of alpha oscillations by demonstrating that a decrease in alpha oscillations reflects the engagement of higher-level language areas. The stage is now set for investigating how the involved areas functionally interact in order to support the generation of predictions.

- **Nicola Molinaro and Mikel Lizarazu** (Basque Center on Cognition, Brain and Language, Spain)
  "The role of cortical oscillations during speech processing"

  Speech comprises hierarchically organized rhythmic components that represent prosody (delta band), syllables (theta band) and phonemes (gamma band). During speech pre-processing steps, neural oscillations within a fronto-temporo-parietal network track these quasi-rhythmic modulations through different mechanisms (de-multiplexing and segmentation steps). Speech processing models associate neural computations in temporal regions to perceptual processes, while operations in frontal-parietal regions are linked to higher-order processes (attention). However, there is no comprehensive view of the neural dynamics that allow perceptual and attentional processes to interact before extracting meaning from speech. In the present study, we analyzed MEG data from 20 participants while hearing continuous speech. First, we determined how different brain areas within the fronto-temporo-parietal network deal with the de-multiplexing (Coherence analysis) and the segmentation (Phase Amplitude Coupling analysis) pre-processing steps. Then, we showed how low-frequency (delta and theta band) neural oscillations bidirectionally connect (Transfer Entropy analysis) temporal and fronto-parietal areas. Our results indicate that, during continuous speech processing, cortical oscillations represent an ideal medium to deal with perceptual and attentional neural computations, as well as to control interactions between these cognitive operations.

- **Lars Meyer** (Univ. of Potsdam, Germany)
  "Chunk, Store, and Integrate: Neural Oscillations during Sentence Comprehension"

  Sentence comprehension is often conceptualized as a set of working-memory operations: Speech is chunked into phrases, which are stored for the establishment of dependencies with other phrases, and which are integrated with other phrases on dependency establishment. Prior research on speech and working memory generates hypotheses for the neural-oscillatory mechanisms behind these operations. As a first example from speech research, delta-band oscillations entrain to intonation phrases—from which I hypothesized implications for phrasal chunking. As a second example from working-memory research, alpha-band oscillations are involved working-memory storage—from which I hypothesized the alpha band's involvement in phrase storage. As a third example, long-distance theta-band synchronization underlies retrieval of items from the brain's memory systems—from which I hypothesized a role of the theta band in the integration of stored phrases. In this talk, I will present recent evidence for my hypotheses: First, phrasal chunking is predicted by delta-band phase. Second, increases in left-parietal alpha-band power accompany the storage of phrases. Third, phrase integration is accompanied by long-distance theta-band synchronization between storage and control brain regions. The functional brain network of sentence comprehension thus appears to tap into principles of information processing and transfer that are common across domains.