Complex sensory stimuli entrain brain oscillations

Organizer: Joachim Gross

Room:# 103

Date and Time: Monday, October3 / 08:30-10:30

Entrained Brain Oscillations and the Processing of Complex Auditory or Visual Stimuli
There is a growing number of studies demonstrating a temporal reorganization of human brain oscillations in response to complex quasi-rhythmic stimuli such as speech. The reorganization is characterized by a temporal alignment of frequency-specific brain activity to stimulus features. However, the differential contributions of bottom-up and top-down processes to this alignment have remained largely unknown. Furthermore, we are just beginning to understand what physical stimulus features and what linguistic structures are entraining brain activity. Recent studies suggest that this entrainment reflects cognitive processes of temporal coding, segmentation and prediction that are orchestrated by hierarchically organized brain oscillations. In this symposium we are presenting and discussing the latest developments in this field. Specifically, we explore the role of brain oscillations in the coding and parsing of hierarchical linguistic structures and the top-down modulation of bottom-up entrainment through visual and auditory sensory channels. Through presentations and discussions our symposium aims to contribute to a better understanding of how rhythmic brain activity assists in the processing of complex, naturalistic stimuli and, ultimately, facilitates human communication.

Speakers:

- **David Poeppel** (New York Univ., USA/Max Planck Inst. for Empirical Aestetics)
  "Cortical entrainment to abstract structures in language"

  I discuss recent electrophysiological studies that focus on a general question about the neural implementation of language comprehension. Based on a set of experiments using MEG and ECoG, I develop how temporal encoding can form the basis for more abstract, structural processing. The results demonstrate that, during listening to connected speech, cortical activity of different time scales is entrained concurrently to track the time course of linguistic structures at different hierarchical levels (words, phrases, sentences). Importantly, the neural entrainment to hierarchical linguistic structures is dissociated from the neural encoding of acoustic cues as well as from processing the predictability of incoming words. These results demonstrate syntax-driven, internal construction of hierarchical linguistic structure via entrainment of hierarchical cortical dynamics. The conclusion — that language is syntactic-structure-driven — provides a new neurobiologically motivated provocation to the prevailing view that language comprehension is ‘mere' statistics.

- **Hyojin Park** (Univ. of Glasgow, UK)
  "Lip movements during speech entrain observers’ low-frequency brain oscillations"

  During continuous speech, lip movements contain rhythmic visual components that facilitate speech processing by the observer. Here, using MEG we investigated for the first time directly how these rhythms interact with rhythmic brain activity in participants watching movies of a speaker. Our study consisted of four main steps. First, we investigated coherence between oscillatory brain activity and speaker’s lip movement and demonstrated significant entrainment in visual cortex. Second, we compared this synchronization at different levels of attention and found that enhanced attention to visual speech leads to enhanced synchronization in visual cortex. Third, we used partial coherence to remove contributions of the coherent auditory speech signal from the lip-brain. This analysis identified significant coherence between left motor cortex and lip movements. Fourth, we demonstrate that this coherence predicts

comprehension accuracy. Our results emphasize the importance of visually entrained and attention-modulated rhythmic brain activity for the enhancement of audiovisual speech processing.

- **Jonas Obleser** (Univ. of Lübeck, Germany)
"The oscillatory dynamics of auditory attention"

  Listening requires us to regulate auditory attention dynamically in time and space. Listeners must be able to, on the one hand, follow the temporal structure of acoustic stimulation (i.e., “entrain” to the sensory environment) and on the other hand disengage (i.e., “functionally inhibit“) brain areas processing task-irrelevant information at certain times. A guiding hypothesis of our work asserts that neural oscillatory entrainment (~1–5 Hz) index a listener’s faithful tracking of acoustic stimuli, while the power of alpha oscillations (~8–13 Hz) reveals the deployment of top-down control. I will present evidence from electro-/magnetoencephalography studies showing that listeners use both mechanisms to regulate auditory attention. First, when attending to one of two concurrent speech streams, sensory entrainment and alpha power lateralization are in sync with the on-going speech stream, but lag each other. Second, individual’s ability to utilize an attentional cue for improved precision in sensory memory can be predicted by the degree to which alpha power is dynamically increased in the delay period. In sum, these data demonstrate how auditory attention in time and space utilizes two complementary neurobiological mechanisms of bottom-up sensory entrainment versus top-down functional inhibition.

- **Anne Koesem & Virginie van Wassenhove** (CEA DSV/I2BM, INSERM, NeuroSpin center, France)
"Oscillatory neural activity controls the encoding of continuous speech"

  During speech listening, the brain parses a continuous acoustic stream of information into computational units (e.g. syllables or words) necessary for speech comprehension. Recent hypotheses have proposed that neural oscillations contribute to speech parsing but whether they do so on the basis of acoustic cues (bottom-up acoustic parsing) or as a function of available linguistic representations (top-down linguistic parsing) is unknown. In this magnetoencephalography study, we contrasted acoustic and linguistic parsing using bistable speech sequences. While listening to speech sequences, participants were asked to maintain one of the two possible speech percepts through volitional control. We predicted that the tracking of speech dynamics by neural oscillations would not solely follow the acoustic properties but also shift in time according to participant’s conscious speech percept. Our results show two dissociable markers of neural-speech tracking under endogenous control: small modulations in low-frequency oscillations and variable latencies of high-frequency activity (sp. beta and gamma bands). While changes in low-frequency neural oscillations are compatible with the encoding of pre-lexical segmentation cues, high-frequency activity specifically informed on an individual’s conscious speech percept.