NEURAL OSCILLATIONS IN SPEECH AND LANGUAGE PROCESSING
BERLIN, 28-31 MAY 2017

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Opportunities pertaining to the question what brain oscillations entrained across all A1 neuronal ensembles in the non-human primate act as a spectro-temporal filter is organized in cortical areas wakefulness vs. sleep, as an extreme case. Learning to uncover structure: insights from intracranial EEG. Recent evidence suggests that the brain entrains to linguistic and rhythmical stimuli, words, phrases, and sentences simultaneously during speech processing. This is reflected by neural activity at the frequencies at which these linguistic units occur. We discuss studies in which we have used statistical learning paradigms and intracranial recordings to investigate how the brain learns to segment continuous speech into relevant units, and where this takes place. We exposed participants to streams of repeating 3-syllable nonsense words and assessed learning via online measures of inter-trial coherence (ITC), quantifying entrainment at the different segmental units (i.e., at the syllabic and the word level). This allowed us to track where learning occurs and at what timescale learning evolves. We observed that neural sources underlying segmentation are broadly distributed, but show selective representation of the syllable and/or word rates (i.e., 4 Hz and 1.33 Hz, respectively). At the syllable rate, responses are found in areas typically implicated in general auditory processing, such as the superior temporal gyrus, whereas responses at the timescale of words also appear in other association areas, such as frontal cortex. Learning of nonsense words evolved in time, reflected by increasingly stronger rhythm-based frequency, whereas purely syllabic responses remained stable across time. Furthermore, neural entrainment was observed even when participants performed a distractor task, indicating that explicit attention to the segmentation cues is not necessary to drive learning and entrainment. These studies highlight the power of online neural en-
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DAY 2 Tuesday 30 May

09:00 Talk 10

Prof. Dr. Pascal Fries
Ernst Strüngmann Institute (ESI) for Neuroscience in Cooperation with Max Planck Society, Frankfurt, DE

Rhythms for Cognition: Communication Through Coherence

I will show that free viewing induces gamma-band oscillations in early visual cortex. If the gamma rhythm in a lower visual area entrains a gamma rhythm in a higher visual area, this might establish an effective communication protocol: The lower area sends a representation of the visual stimulus rhythmically, and the higher area is most excited when this representation arrives. At other times, the higher area is inhibited, which excludes competing stimuli. I refer to this as the Communication-Through-Coherence (CTC) hypothesis. I will show that the gamma rhythm in awake macaque V4 modulates the gain of synaptic inputs. I will further show that constant optogenetic stimulation in anesthetized cat area 21a (homolog to V4) induces a local gamma rhythm, and that this isolated gamma is sufficient to produce similar gain modulation. These gain modulation effects would be ideal to lend enhanced effective connectivity. I will show that this is indeed the case between macaque V1 and V4. When two visual stimuli induce two local gamma rhythms in V1, only the one induced by the attended stimulus entrains V4. I will then investigate how these changes in gamma synchronization between visual areas are controlled by influences from parietal cortex. I will show that posterior parietal cortex influences visual areas primarily via beta-band synchronization. I will show that generally, beta-band influences are stronger in the top-down direction, while gamma-band influences are stronger in the bottom-up direction. This holds across macaques and human subjects, and in both species it allows building a hierarchy of visual areas based on the directed influences. Finally, I will show how we can achieve a similar gamma response at a theta rhythm. When two objects are monitored simultaneously, attentional benefits alternate at 4 Hz, consistent with an 8 Hz sampling rhythm, sampling them in alternation.

11:45 Talk 13

Prof. Nancy Kopell, PhD
Department of Mathematics & Statistics, Boston University

Gamma, Beta and Predictions

A violation of expectation can lead to an increase or a decrease in the power of brain rhythms (gamma and beta). This talk discusses physiological mechanisms that could underlie the opposite outcomes, as well as potential implications for speech processing.

12:30 Talk 14

Dr. Lars Meyer
Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, DE

The Purpose of Synchronicity: Neural Oscillations Align Excitability with Linguistic Informativeness

In auditory neuroscience, there is emerging consensus that neural oscillations phase-synchronize with frequency-somorphous acoustic and linguistic rhythms in speech. Yet, the tracking of certain rhythms is not language comprehension—which requires the understanding of the syntactic and semantic information that speech actually symbolizes. I will present here evidence that oscillatory synchronicity may indeed facilitate linguistic information processing. First, I will show that delta-band oscillatory phase can drive sentence interpretations that contradict acoustic cues. Second, I will show that oscillatory synchronicity aligns neural excitability (as indexed by delta-band oscillatory phase and ERPs) with linguistic informativeness (as quantified by information-theoretic metrics) facilitating language comprehension (as measured through a high-level linguistic task). I will argue that phase-synchronization during speech processing is not a self-contained mechanism to ensure high-fidelity rhythm tracking; instead, phase-synchronization can optimally align information extraction capacities with linguistic informativeness.

13:15 Lunch (HH Canteen)

14:00 Talk 15

Prof. Rufin VanRullen, PhD
Department of Mathematics & Statistics, Boston University

Perceptual cycles in vision and audition

Recent (and less recent) evidence suggests that visual perception and attention are intrinsically rhythmic. For a variety of visual tasks, the trial-by-trial outcome was found to depend on the precise phase of spontaneous pre-stimulus EEG oscillations in specific frequency bands (between 7 and 15Hz). This implies that there are “good” and “bad” phases for visual perception and attention; in other words, visual perception and attention proceed as a succession of ongoing cycles. On the other hand, auditory processing does not appear to be shaped in a similar way by spontaneous brain oscillations. Particularly in the context of speech processing, where the rhythmic structure of the inputs carries important information, neural oscillations are dynamically adjusted to this input structure. As a result, auditory perceptual cycles, if they exist, would not just shape sensory perception (as in vision), but also be shaped by it.

14:45 Talk 16

Prof. Virginie Wassenhove, PhD
Cognitive Neuroimaging Unit, CEA DRF/I2BM, INSERM, Paris-Saclay University, Paris-Saclay University, Neuroimaging Center, Gif/Yvette, Fr

Neural oscillations: reconciling timing and meaning

Neural oscillations have been implicated in various cognitive functions, highlighting their logistical relevance in timing cognition. In humans, cortical oscillations continuously send and receive signals into computational units (e.g. syllables or words) necessary for speech comprehension.
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Neural oscillations may serve as natural parsers for bottom-up acoustic parsing and may also be top-down maneuvers for top-down linguistic representations. Using magnetoencephalography, we contrasted acoustic and linguistic parsing using bistimulus presentations: while listening to speech sequences, participants were asked to maintain one of the two possible speech perceptions through volitional control. The tracking of speech dynamics by neural oscillations was predicted to not solely follow the acoustic properties but perhaps shift in time according to participants' conscious speech percept. Our results showed two dissociable markers of neural-speech tracking under endogenous control: small modulations in low-frequency oscillations and variable latencies of high-frequency activity (e.g., beta and gamma bands). While changes in low-frequency neural oscillations are compatible with the encoding of pre-lexical segmentation cues, high-frequency activity informed an individual's conscious speech percept. These and other results will help feed a discussion on the functional role of neural oscillations in representing meaning and/or time.

15:30 Talk 17

Dr. Simon Hanslmayr, PhD
School of Psychology, University of Birmingham, GB

Searching for memory in brain waves – The synchronization/desynchronization conundrum

Brain oscillations have been proposed to be one of the core mechanisms underlying episodic memory. But how do they operate in the service of memory? Recent work using the literature a co-nundrum emerges as some studies highlight the role of synchronized oscillatory activity, whereas others highlight the role of desynchronized activity. In this talk I will describe a framework that potentially resolves this conundrum and integrate these two opposing oscillatory behaviours. I will present novel studies using different techniques to study oscillations (i.e. from EEG/MEG, EEG/fMRI, to human single unit and LFP recordings) and argue, based on these findings, that the synchronization and desynchronization reflect a division of labour between a hippocampal and a neocortical system, respectively. Specifically, whereas desynchronization is key for the neocortex to represent information, synchronization in the hippocampus is key to bind information. This talk will present a framework in which oscillatory activity framework in- tergrates synchronization and desynchronization mechanisms in order to explain how the two systems (i.e. neocortex and hippocampus) interact in the service of episodic memory. Finally, I will discuss open questions, specific predictions and challenges that follow from this framework.

16:15 Poster Session

19:00 Dinner (Restaurant)

21:00 Hangout in bar/pub

DAY 3

Wednesday 31 May

09:00 Talk 18

Vitória Magalhães Piai, PhD
Radboud University, Donders Institute for Brain, Cognition and Behaviour and Radboud University Medical Center, Department of Medical Psychology, Nijmegen, NL

Oscillations as a bridge between language and other cognitive domains

Language comprehension and production rely on memory and control processes. In addition, the motor system is recruited for language production. Memory, motor, and control processes are well-studied outside of the language domain. I will argue that oscillations may constitute the best measure to understand language in relation to these other domains. In particular, I will discuss alpha-beta oscillations in the lateral cortex with respect to memory and motor aspects of word production, and gamma oscillations in the hippocampal theta oscillations, which are tightly related to episodic memory, track the amount of mnemonic associations in sentence contexts. I will also show how resolving competition between words in language production is associated with theta oscillations in the medial frontal cortex, a signature of executive function. Finally, I will discuss what these neuronal signatures can reveal about language lateralisation and neu- roplasticity in patient populations.

09:45 Talk 19

Prof. Christoph Kayser, PhD
Institute of Neurosciences and Psychology, University of Glasgow, GB

Audio-visual speech integration mediated by changes in local encoding and functional connectivity

Seeing a speaker's face enhances speech intelligibility in adverse environments. We investigated the underlying network mechanisms by quantifying local speech representations and directed connectivity at brain oscillation frequency bands. We showed that when human participants listened to speech varying acoustic SNR and visual context in two paradigms, one paradigm involved the presentation of long- continuous texts, while the other tested perceptual benefits on the single sentence level. We found that during speech, neural responses during the encoding of entrained brain activity was strong in temporal and inferior frontal cortex, while during low SNR strong entrainment emerged in premo- tor and superior frontal cortex. These changes in local encoding were accompanied by changes in directed connectivity along the ventral stream and the auditory-premotor axis. Importantly, the behavioural benefit arising from seeing the speaker's face was not predicted by changes in local encoding but rather acoustic SNR speech en- coding by entrained brain activity was strong in inferior frontal cortex, and during low SNR strong entrainment emerged in premo- tor and superior frontal cortex. Our results demonstrate a role of auditory-motor interactions in visual speech representations and suggest that functional connectivity along the ventral pathway facilitates speech comprehension in multisensory environ- ments.

10:30 Coffee Break 4

11:00 Talk 20

Prof. Dr. Christoph S. Herrmann, Dr. Anna Wilsch
Carl von Ossietzky Universität Oldenburg, DE

Transcranial current stimulation with speech envelopes enhanced intelligibility

Cortical entrainment of the auditory cortex to the broadband temporal envelope of a speech signal is crucial for speech comprehension. En- trainment results in phases of high and low neural excitability which structure and decode the incoming speech signal. Entrainment to speech is strongest in the theta frequency range (4–8 Hz), the average frequency of the speech enve- lope. If a speech signal is degraded, entrainment to the speech envelope is weaker and speech intelligibility declines. Besides perceptually evoked cortical entrainment, transcranial alter- nating current stimulation (TACS) entrains neural oscillations by applying an electric signal to the brain. Accordingly, TACS-induced entrainment in auditory cortex has been shown to improve au- ditory perception. The aim of the current study was to modulate speech intelligibility externally by means of TACS such that the electric current corresponds to the envelope of the presented speech stream. Participants performed the Old- enburg sentence test with sentences presented in noise in combination with TACS. Critically, TACS was stimulated with time-lags of 0 to 250 ms in 50-ms steps relative to sentence onset (auditory stimuli were simultaneous or to preceded TACS). We were able to show that envelope-TACS mod- ulated sentence comprehension such that sen- tence comprehension at the time-lag of the best performance was significantly better than at the time-lag of the worst performance. Interestingly, sentence comprehension across time lags was modulated sinusoidally. Altogether, envelope TACS modulates intelligibility of speech in noise presumably by enhancing and disrupting (time- lags resulting in in- or out-of-phase stimulation, respectively) cortical entrainment to the speech envelope in auditory cortex.

11:45 Talk 21

Prof. Dr. Jonas Obleser
Department of Psychology, University of Lübeck, DE

Comprehending the patterns: Patterns of comprehension

The renewed interest in neural oscillations and the methodological advances in characterising them has flooded us with empirical results. A clear pattern of frequency-to-function assign- ment is yet to emerge, however: it remains tempting to speak of brain rhythms like neuro-imaging enthusiasm made us speak of brain re- gions fifteen years ago (“The superior temporal sulcus does X” and “the theta does Y”). In my view, it is not only foreseeably wrong but also unnec- essary that speech and language science repeat these same mistakes. By analysing and interpreting electrophysiological signals in the time–frequency domain. For this workshop, I would like to discuss (and exemplify using the attentive, speech-comprehending brain) how a more parsimonious, neurophysi- ologically grounded framework should at least help us in avoiding some of these methodologi- cal traps. While trying not to fall prey to the crit- icism outlined above, I will aim at synthesising evidence from our and other labs on how attent- ive listening and speech comprehension in all likelihood manifests in at least two, distinct pro- cessing modes or patterns: Slow-oscillatory “en- trainment” (presented alongside a more careful definition of what we should denote by that and what not) trading off against faster (alpha/beta) “modulation”, or goal-driven inhibition.