Oral | Prediction, Temporal perception, Computational Modeling

Sat. Oct 18, 2025 1:00 PM - 2:30 PM JST | Sat. Oct 18, 2025 4:00 AM - 5:30 AM UTC Venue 3(KOMCEE W Lecture Hall)

[O6] Oral 6: Prediction, Temporal perception, Computational Modeling

Chair:Pascal Mamassian(CNRS & Ecole Normale Supérieure Paris)

1:00 PM - 1:15 PM JST | 4:00 AM - 4:15 AM UTC

[O6-01]

Temporal Prediction through Integration of Multiple Probability Distributions of Event Timings

*Yiyuan Teresa Huang[1], Zenas C Chao[1] (1. International Research Center for Neurointelligence, The University of Tokyo (Japan))

1:15 PM - 1:30 PM JST | 4:15 AM - 4:30 AM UTC

[O6-02]

The anticipation of imminent events is time-scale invariant

*Matthias Grabenhorst[1,2], David Poeppel[3], Georgios Michalareas[4,1,2] (1. Ernst Struengmann Institute for Neuroscience (Germany), 2. Max Planck Institute for Empirical Aesthetics (Germany), 3. New York University (United States of America), 4. Goethe University (Germany))

1:30 PM - 1:45 PM JST | 4:30 AM - 4:45 AM UTC

[O6-03]

The timing of neural-cardio-respiratory network states predicts perception across the senses

*Andreas Wutz[1] (1. University of Salzburg (Austria))

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[O6-04]

What does the Fröhlich effect tell us about sensation time?

*Pascal Mamassian[1] (1. CNRS & Ecole Normale Supérieure Paris (France))

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[O6-05]

Oscillatory Entrainment in Non-Deterministic Continuous Environments, Independent of Bayesian Interval Learning: Computational and Behavioral Evidence

*Elmira Hosseini[1,2], Assaf Breska[1] (1. Max-Planck Institute for Biological Cybernetics (Germany), 2. Tübingen University (Germany))

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[O6-06]

An investigation of auditory rhythms with a spiking neural network autoencoder

*Rodrigo Manríquez[1,2], Sonja A. Kotz[2,3], Andrea Ravignani[4,5], Bart de Boer[1] (1. Vrije Universiteit Brussel (Belgium), 2. Maastricht University (Netherlands), 3. Max Planck Institute for Human Cognitive and Brain Sciences (Germany), 4. Sapienza University of Rome (Italy), 5. Aarhus University & The Royal Academy of Music (Denmark))

Temporal Prediction through Integration of Multiple Probability Distributions of Event Timings

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Our brain uses prior experience to anticipate the timing of upcoming events. This dynamical process can be modeled using a hazard function derived from the probability distribution of event timings. However, the contexts of an event can lead to various probability distributions for the same event, and it remains unclear how the brain integrates these distributions into a coherent temporal prediction. In this study, we create a foreperiod sequence paradigm consisting of a sequence of paired trials, where in each trial, participants respond to a target signal after a specified time interval (i.e. foreperiod) following a warning cue. The prediction of the target onset in the second trial can be based on the probability distribution of the second foreperiod and its conditional probability given the foreperiod in the first trial in the context of foreperiod sequence. These probability distributions are then transformed into hazard functions to represent the temporal predictions. The behavioral model incorporating both of the prediction and the contextual prediction significantly improves fit of reaction times to the target signal, indicating that both regularities of temporal information contribute to making predictions. We further show that electroencephalographic source signals are best reconstructed when integrating both predictions. Specifically, the prediction and the contextual predictions are separately encoded in the posterior and anterior brain regions, and to achieve synergy between both predictions, a third region—particularly the right posterior cingulate area—is needed. Our study reveals brain networks that integrate multilevel temporal information, providing a comprehensive view of hierarchical predictive coding of time.

Keywords: Temporal prediction, Multiple probability distributions, Hazard functions, Forward encoding analysis, EEG source

The anticipation of imminent events is time-scale invariant

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Humans predict the timing of imminent events to generate fast and precise actions. Such temporal anticipation is critical over the range of hundreds of milliseconds to a few seconds. However, it was argued that timing mechanisms differ below and above a boundary at around 1–2 seconds in time perception and interval discrimination (Grondin, J Exp Psychol, 2012; Gibbon et al., Curr Opin Neurobiol, 1997) and duration discrimination (Rammsayer & Lima, Percept Psychophys, 1991; Rammsayer et al, Frontiers in Psychology, 2015) which may affect timing behavior in the anticipation of imminent events. Recent work showed that the brain models the probability density function of events across time, suggesting a canonical mechanism for temporal anticipation (Grabenhorst et al., Nat Commun, 2019 & 2025). Here we investigate whether this core computation remains stable across the described temporal boundaries when the distribution of events is stretched across different time spans. In a Set - Go task, the time between the two cues was randomly drawn from probability distributions which, across experimental blocks, were defined over different time spans. Participants were asked to react as fast as possible to the Go cues and generated > 52000 reaction times (RT). We found that, irrespective of the time span, anticipation, measured as RT, scales with the event distribution. This shows that the key computation –the estimation of event probability density –is invariant across temporal scales. We further found that the variance in anticipation is also scale invariant which contradicts Weber’s law. The results hold in vision and audition, suggesting that the core computations in anticipation are independent of sensory modality. These findings demonstrate that –independent of temporal scale –perceptual systems estimate probability over time to anticipate the timing of future events. We conclude that temporal anticipation, a basic function in cognition, is time-scale invariant.

Keywords: Temporal prediction, Probability estimation, Time estimation, Temporal cognition, Weber's law

The timing of neural-cardio-respiratory network states predicts perception across the senses

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For the past decades, neuroscience research has repeatedly highlighted the pivotal role of observer-dependent, internal network states predisposing sensory experiences in the external world. Nevertheless, many open questions remain: How are these internally generated processes implemented in the perceiver? How are they controlled and timed relative to each other and to sensory inputs? And, do they generalize across different sensory systems? In this talk, I present novel magneto-encephalography (MEG), cardiac and respiratory data that conclusively demonstrate top-down brain networks influencing perception across different sensory modalities and their relationships to ongoing dynamics in the body. On each trial, different visual, auditory or tactile stimuli were shown at individual perceptual thresholds, such that about half of the stimuli were consciously detected, while the other half were missed. The main findings show neural activity bursts occurring shortly before stimulus onset across frontal and posterior cortex in the brain's dominant alpha-frequency band rhythm (8-13 HZ). The precise timing of these neural activity bursts is predictive of subsequent perceptual outcomes generalized across all three senses. Moreover, the neural activity bursts happen at specific phases of the participants' cardiac cycle, suggesting a crucial role of pre-stimulus neural-cardio network timing for conscious perception. Because cardiac activity is strongly coupled to respiration, neural-cardio network interactions may be top-down controlled and timed by the participants' breathing behavior. In line with this hypothesis, the participants strategically regulate their respiratory activity during the task both relative to stimulus onset and to neural burst onset. The participants' breath out earlier for successfully detected vs. missed stimuli with respect to the onset of the activity bursts in the brain. Overall, our results reveal an interactive, multi-stage temporal processing cascade bridging both neural and bodily systems and preparing the perceiving organism for the optimally timed integration of conscious experiences.

Keywords: perception , oscillations, MEG, brain-body interactions

What does the Fröhlich effect tell us about sensation time?

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When an object suddenly appears and starts moving, its initial position is often mislocalized in its direction of motion. In 1923, Friedrich Fröhlich used this effect to measure the “sensation time”, i.e. the time between the impact of light on the retina and the corresponding visual sensation. He reasoned that sensation time can be directly inferred from the spatial bias, given the object speed. This reasoning has since been heavily criticised and new interpretations for the Fröhlich effect have been offered, in particular one based on a spatial prediction that extrapolates into the future to compensate for neural delays. Does this mean that the Fröhlich effect is useless to measure sensation time? We addressed this question by manipulating the duration of a moving object from 50 to 300ms. For the same observers in different experiments, we asked them to report the perceived spatial onset of a small moving disc, its perceived offset, its perceived duration, and its perceived speed. To control for possible eccentricity effects, the object rotated along a visible circle centered on the fixation point. This path was divided into two sectors of different colours, half was blue and the other half orange, and the colour boundaries defined reference marks that observed used to report their perceived onset or offset (e.g. “was stimulus onset in the blue or orange sector?”). Surprisingly, we found an “anti-Fröhlich” effect: the perceived spatial onset was before the start of the motion, at a location that the object never occupied. We also found that perceived speed was largely overestimated, and more so for shorter durations. Finally, we did not find any significant bias in perceived offset or perceived duration. Overall, these results are consistent with a global inference of perceived duration, speed, onset and offset locations, all at the same time at the end of the motion. We argue that this delay relative to the object appearance is informative about sensation time.

Keywords: sensation time, Fröhlich effect, motion perception, visual psychophysics

Affective modulation of temporal binding using linguistic stimuli

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Temporal binding (TB)—the perceived shortening of time between a cause (event A) and its effect (event B)—is often associated with voluntary action. This temporal compression is typically stronger when the action is self-generated, making TB a widely used implicit marker of the sense of agency (SoA). Whereas explicit measures of SoA are usually sensitive to outcome valence (positive outcomes yield higher agency ratings than negative ones), implicit measures such as TB have produced less consistent findings. We examined whether emotional valence influences TB using a two-alternative forced-choice (2AFC) interval discrimination task in three experiments, varying the predictability of outcome valence. Emotional words (e.g., "joy," "death," "chair") served as outcomes, categorized as positive, negative, or neutral. Relevant psycholinguistic variables were matched across valence groups using previous normatization studies for Brazilian Portuguese and two online surveys (N = 54). In Experiment 1 (N = 33), agency (active vs. passive) and word valence were fixed within blocks. In Experiment 2 (N = 40), valence was either fixed or varied across trials, depending on the block. Experiment 3 (N = 40) used only trial-wise variation in valence. Across all experiments, generalized linear mixed models (GLMMs) replicated the TB effect: active trials were perceived as more temporally compressed than passive ones. However, outcome valence did not interact with agency in any of the experiments, suggesting no affective modulation of TB. These findings suggest that emotional valence alone may not be sufficient to influence implicit measures of agency, such as TB. Future research should investigate additional factors and methodologies to gain a deeper understanding of how emotion, agency, and time perception interact.

Keywords: Temporal binding, Sense of Agency, temporal cognition, psychophysics, cognitive-affective neuroscience

An investigation of auditory rhythms with a spiking neural network autoencoder

*Rodrigo Manríquez[1,2], Sonja A. Kotz[2,3], Andrea Ravignani[4,5], Bart de Boer[1]

1. Vrije Universiteit Brussel, 2. Maastricht University, 3. Max Planck Institute for Human Cognitive and Brain Sciences, 4. Sapienza University of Rome, 5. Aarhus University & The Royal Academy of Music

Here, we present a biologically inspired spiking neural network, or SNN, framework that learns auditory rhythms from acoustic data by exploiting the exact spike timing of spikes. Although classic deep learning models have been applied to investigate temporal sequences, spiking NNs more accurately reflect the temporal dynamics of biological neural systems.

We first encoded acoustic waveforms containing rhythmic information into spike trains and considered a subcortical model of the peripheral auditory pathway [1.] This model reproduces cochlear transduction and auditory-nerve firing across characteristic frequencies, yielding parallel streams of precisely timed spikes that retain the temporal structure of the input. These spike trains were then used to train a purely spike-based autoencoder. In this framework, the encoder compresses input data into a latent representation, i.e. a simplified representation that captures underlying features of the data, while the decoder reconstructs the amplitude envelope of the original sound, preserving rhythmic features.

By training on isochronous sequences, where consecutive onsets were separated by identical intervals, we demonstrate that rhythmic structure is preserved in the latent space representation. Moreover, the network develops predictive behaviour, by anticipating subsequent beat onsets even in the absence of a beat. This sensitivity reflects a form of temporal expectation embedded in the SNN. To evaluate how the network internalises rhythmic structures, we tested it with sequences that missed beats and inspected the resulting latent representations. By analysing the spiking activity and internal variables within this hidden layer, we revealed how the model encodes temporal regularities and reconstructs the expected onset pattern, in a way that would not be possible in a non-spiking neural network.

1. Zuk, N., Carney, L., Lalor, E. 2018. Preferred Tempo and Low-Audio-Frequency Bias Emerge From Simulated Sub–cortical Processing of Sounds With a Musical Beat. *Front. Neurosci.*, *12*.

Keywords: Spiking Neural Networks, Auditory Processing, Rhythm Processing