Oral | Computational Modeling, Neural Mechanisms

Sat. Oct 18, 2025 9:00 AM - 10:30 AM JST | Sat. Oct 18, 2025 12:00 AM - 1:30 AM UTC Venue 4(KOMCEE W B1F-011)

[O5] Oral 5: Computational Modeling, Neural Mechanisms

Chair:Assaf Breska(Max-Planck Institute for Biological Cybernetics)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[O5-01]

Centralized mechanisms of explicit and implicit timing in the human cerebellum: a neuropsychological approach

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9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[O5-02]

Unique Effect of Entrainment on Perception? Context-Specific Temporal Prediction Mechanisms in Multiple Aspects of Perception

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9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[O5-03]

Rationalizing temporal decision making and the neural representation of time

*Marshall G Hussain Shuler[1,2] (1. Johns Hopkins (United States of America), 2. Kavli Neuroscience Discovery Institute (United States of America))

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[O5-04]

A Methodology to Accelerate Our Information Processing Toward Revealing the Relation between Process Speed and Time Perception

*Oki Hasegawa[1], Shohei Hidaka[1] (1. Japan Advanced Institute of Science and Technology (Japan))

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[O5-05]

Sensory Reliability Shapes Sequential Effects in Human Duration Perception

*Taku Otsuka[1,2], Joost de Jong[1,3], Wouter Kruijne[1], Hedderik van Rijn[1] (1. University of Groningen (Netherlands), 2. The University of Tokyo (Japan), 3. Université de Paris (France))

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[O5-06]

Bach and Bayes: Prediction in Noisy Musical Sequences

*Akanksha Gupta[1], Alejandro Tabas[2,3] (1. INS, INSERM, Aix-Marseille University, Marseille (France), 2. Perceptual Inference Group, Basque Center on Cognition, Brain and Language, San Sebastian (Spain), 3. Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig (Germany))

Centralized mechanisms of explicit and implicit timing in the human cerebellum: a neuropsychological approach

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Humans keep track of temporal intervals for various purposes, ranging from explicitly reporting perceived durations to implicitly orienting attention in time. Whether shared or segregated timing mechanisms subserve these timing processes is a key neuroscientific question. While neuroimaging studies revealed task-dependent functional dissociations, mostly at the cortical level, recent behavioral work hints at potential computational overlap. Moreover, separate lines of research have implicated the cerebellum in both explicit and implicit interval timing, but whether this reflects one shared or two task-specific cerebellar circuits is unknown. Here, we investigated how the cerebellum might act as a central timing circuit in implicit and explicit interval timing. Cerebellar Ataxia (CA) patients (N=18) and age-matched neurotypical controls (N=16) performed explicit (temporal discrimination) and implicit (cued temporal orienting for speeded detection) interval timing tasks, as well as a control task to account for non-temporal factors. Two intervals (S1, S2) were sequentially presented: S1 was either short (700ms) or long (1200ms), while S2 spanned between the short and long S1. CA patients' performance was impaired compared to healthy controls in both tasks, showing lower temporal sensitivity in temporal discrimination and smaller validity effect in temporal orienting, in line with previous studies. Critically, the performance in the two tasks was more strongly associated in the patient than the control group, with only the former showing a significant correlation, as predicted by a shared process model. Moreover, this was not explained by non-temporal factors. These findings establish the cerebellum as a central sub-second interval timing hub, causally involved in timing intervals independently of the final purpose.

Keywords: explicit timing, implicit timing, interval timing, cerebellum, cerebellar ataxia

Unique Effect of Entrainment on Perception? Context-Specific Temporal Prediction Mechanisms in Multiple Aspects of Perception

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Temporal prediction and preparation are essential for adaptive behavior, and can be generated based on various temporal regularities, including rhythms and interval memory. In rhythmic streams temporal predictions are thought to uniquely rely on phase-aligning neural oscillations to the external rhythm. However, in motor tasks, previous studies found similar behavioral benefits and neural phase alignment patterns for rhythm- and interval-based temporal predictions, questioning the unique role of entrainment in these phenomena. Yet, if rhythmic entrainment acts at low-level sensory circuits, its unique effect might only be revealed under high perceptual load. Here we address this using a challenging perceptual discrimination task, in which visual target timing is either non-predictable, is on-beat with a preceding rhythm (~1.11 Hz), or matches a previously presented interval (900 ms). Examining the differential effect of temporal expectation on multiple levels of perception, we collect both objective classification accuracy and subjective visibility reports, a fundamental distinction in consciousness research that has been overlooked in the temporal attention literature. In line with previous findings, both interval- and rhythm-based temporal expectations improve performance compared to the irregular stream, but to a similar degree, which is inconsistent with the idea that rhythmic entrainment provides a unique perceptual benefit beyond temporal prediction. In EEG, we critically found similar increases in occipital delta phase alignment in the rhythm and interval conditions. This was not found in central channels, demonstrating the independence of sensory from high-level phase alignment. Taken together, these results show that phase alignment can occur in the absence of oscillatory entrainment and call into question whether rhythmic entrainment provides perceptual benefits beyond what would be expected by temporal prediction alone.

Keywords: temporal attention, rhythmic entrainment, interval, EEG, visual discrimination

Rationalizing temporal decision making and the neural representation of time

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By what neural means do we represent the passage and structuring of time and decide how to spend time? How do these representations of value and time relate to evolutionary pressure to maximize reward accumulation? To address these questions, we evaluate whether the temporal difference reinforcement learning (TDRL) algorithm can rationalize temporal decision-making. First, we derive the *optimal solution* for reward accumulation and demonstrate that TDRL's value estimates—infinite sums of exponentially discounted future rewards—systematically deviate from this optimum. Then we show how TDRL, operating over a time state-space representation using regular intervals, fails to learn values that rationalize the curious pattern of decision-making errors exhibited by humans and animals. Our insight, however, is that this failure can be best mitigated by representing time using a time-dilating state-space, wherein the amount of time spent in a subsequent state increases by a precise proportion. TDRL applied to such a time-dilating state-space then learns values that rationalize the diverse suboptimalities observed over decades of investigating how animals and humans decide to spend time. Specifically, it affords optimal forgo behavior, minimizes a suboptimal bias toward sooner-smaller rewards in mutually exclusive choices, and leads to a suboptimal unwillingness to abandon engaged pursuits (sunk cost). In proposing PARSUIT theory (Pursuit-based Atomized Reinforcement of State-value Using Increasing Timesteps), we provide 1) a general, mechanistically descriptive explanation of temporal decision making, 2) a normative rationalization for why time takes the neural form that it does, and 3) advance TDRL as the learning algorithm used in temporal decision-making.

Keywords: Temporal Difference Reinforcement Learning, reward-rate maximization, dilating time state-space, temporal decision-making

A Methodology to Accelerate Our Information Processing Toward Revealing the Relation between Process Speed and Time Perception

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The subjective experience of time slowing down during peak performance, or 'flow', suggests a link between cognitive processing speed and time perception. However, this relationship is not well understood due to the limitations of short-duration tasks, which are typically employed in psychological and neurological laboratory studies. This is a critical limitation, as the phenomena of interest typically emerge during continuous, sustained activities in the real world. Therefore, to properly test our central hypothesis—an extension of Treisman’ s internal clock model which posits that a high-arousal state accelerates an internal pacemaker to simultaneously improve information processing speed and extend subjective time —an experimental paradigm capable of inducing and continuously sustaining such a state is first necessary. Here, we present this paradigm, which involves an adaptive Tetris game designed to induce a flow-like state and enable a continuous study of the aforementioned link. The system uses a Markov process model to estimate players' abilities and adjust the task's difficulty in real time. To validate this approach, we first measured baseline performance in an ideal, untimed version of the task, confirming that player performance fell within the range predicted by our model. We then investigated the effect of three patterns of difficulty change —linear increase, linear decrease and random —on processing speed (lines cleared per minute). Although players achieved a similar maximum performance level at the end of the game in all conditions, performance improved most quickly under the linearly increasing difficulty condition. These results demonstrate that an adaptive challenge that continuously and predictably increases in response to a player's ability is a key factor for accelerating cognitive processing. At this conference, we will report on the preliminary performance evaluation of the developed task system.

Keywords: Flow State, Infomation Processing Speed

Sensory Reliability Shapes Sequential Effects in Human Duration Perception

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Perceived durations are biased towards immediately preceding percepts. Although such sequential effects in time perception have long been recognized, the Bayesian framework has recently emerged as a compelling account of these phenomena. Crucially, while the Bayesian framework posits that the magnitude of the sequential effect depends on the reliability of both the previous and current stimuli, empirical support for this prediction remains lacking. In order to test this central prediction of the Bayesian framework, we systematically manipulated the perceptual noise of to-be timed stimuli by embedding them in dynamic visual noise. We found that reproduced durations were biased towards the duration of the preceding stimulus, confirming the presence of a sequential effect. Importantly, the magnitude of this effect was modulated by the reliability of both the previous and current stimuli, in a manner consistent with Bayesian predictions. Furthermore, by fitting a Bayesian computational model that updated prior expectations on a trial-by-trial basis, we demonstrated that manipulating the uncertainty of the current sensory input (likelihood variance) enabled the model to capture the observed reliability-dependent modulation of the sequential effect. These findings provide direct empirical evidence for reliability-based integration in human duration judgements and highlight the sequential effect as an adaptive mechanism that dynamically adjusts to sensory uncertainty.

Keywords: sequential effect, Bayesian modeling, duration reproduction, sensory reliability

Bach and Bayes: Prediction in Noisy Musical Sequences

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Information from the external environment is often uncertain and ambiguous, posing a challenge for the brain to accurately infer the state of the world. According to the predictive processing framework, prior knowledge pertinent to inference is compressed into predictions about imminent future states. These predictions are combined with sensory inputs using Bayesian belief updating. While this approach is optimal for inferring latent states in certain stochastic systems, it may not be useful when applied to more complex systems such as music or language. In this work, we examine whether neural networks trained to infer the current latent state in a musical sequence also develop a capacity to predict what comes next.

To investigate this hypothesis, we utilized tokenized Bach compositions corrupted with noise as sensory inputs and gated recurrent neural networks (GRUs) to model neural circuits. The training procedure involved two stages: first, to infer the current token, and then, to optimize a linear readout for predictions of the next token to see if the predictions are encoded in the network's internal states. Furthermore, we benchmarked the network’s performance against an optimal Markovian model, which predicts the next token using only the current token. Our findings demonstrate that neural circuits fine-tuned for perceiving the current state can learn to predict future sensory input, suggesting that predictive capabilities emerge as a consequence of such optimization. This evidence strengthens the computational foundation of the predictive coding framework and offers insights into how biological systems may utilize prior knowledge to adaptively operate within uncertain environments.

Keywords: Predictive Processing, Bayesian Brain Hypothesis, Recurrent Neural Networks (RNNs), gated recurrent neural networks (GRUs)