

Poster | Other

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[P3] Poster: Day 3

[P3-01]

Perceiving Time in Sleep: Links between Misperception, REM Sleep, and Depressivity in Insomnia

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[P3-02]

Implicit, but not explicit, timing is perturbed in schizophrenia

*Jennifer T Coull¹, Laurie Ladame¹, Mounira Taghdouini Kaddour¹, Tiffanie Zemour¹, Hélène Wilquin¹ (1. Centre for Research in Psychology & Neuroscience, CNRS & Aix-Marseille University (France))

[P3-03]

A Deep Reinforcement Learning Approach to Modeling Rat Behavior in Peak Interval Procedure

*S. Ruiz de Aguirre¹, Gloria Ochoa-Zendejas², Jonathan Buriticá² (1. Independent (Mexico), 2. Lab. of Cognition and Comparative Learning, Univ. of Guadalajara-CEIC, Guadalajara (Mexico))

[P3-04]

Complex impact of stimulus envelope on motor synchronization to sound

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[P3-05]

Entrainment in Low- and High-Level Ventral Visual Regions Does Not Affect Temporal Overestimations

*Amirmahmoud Houshmand Chatroudi^{1,2}, Yuko Yotsumoto¹ (1. The University of Tokyo (Japan), 2. Sony Computer Sciences Laboratories (Japan))

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Does Semantic Modulation Induce Time Dilation? The Role of Flicker Frequency and Visual Saliency

*Takeya Oda¹, Amirmahmoud Houshmand Chatroudi², Yuko Yotsumoto¹ (1. The University of Tokyo (Japan), 2. Sony Computer Science Laboratories (Japan))

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Top-Down Control of Alpha-Band Phase as a Mechanism of Interval Temporal Prediction: Direct Test and Preliminary Evidence

*Christina Bruckmann^{1,2}, Assaf Breska¹ (1. Max Planck Institute for Biological Cybernetics (Germany), 2. University of Tübingen (Germany))

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Aging effect on temporal processing: an ongoing study on retrospective timing and spontaneous oscillatory bursts.

*Florentine Fricker¹, Giulia Buzi¹, Maëlys Morantin¹, Franck Doidy¹, Patrice Clochon¹, Raphaël Bordas², Virginie van Wassenhove², Thomas Hinault¹ (1. Université de Caen Normandie, INSERM, EPHE-PSL, PSL University, CHU de Caen, GIP Cyceron, U1077, NIMH, 14000 Caen, France. (France), 2. Cognitive Neuroimaging Unit, INSERM, CEA, Université Paris-Saclay, NeuroSpin, 91191 Gif/Yvette, France. (France))

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Neural Oscillatory Entrainment in Non-Deterministic Continuous Environments, decoupled from Bayesian Interval Learning

*Elmira Hosseini^{1,2}, Assaf Breska¹ (1. Max-Planck Institute for Biological Cybernetics (Germany), 2. Tübingen University (Germany))

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Perceived time shapes the course of physical fatigue

*Pierre-Marie Matta^{1,2,3}, Robin Baurès^{1,2}, Julien Duclay^{1,3}, Andrea Alamia^{1,2} (1. University of Toulouse (France), 2. Centre de Recherche Cerveau et Cognition, CNRS (France), 3. Toulouse NeuroImaging Center, INSERM (France))

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*Mitsuki Niida¹, Kenji Ogawa¹ (1. Hokkaido University (Japan))

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*Chloe Mondok¹, Martin Wiener¹ (1. George Mason University (United States of America))

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*Keying Wang¹, Nilli Lavie¹ (1. University College London (UK))

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*Shu Sakamoto^{1,2}, Emily Wood^{1,2}, Harris Miller¹, Ellia Baines¹, Kevin Yang¹, Lily Eshraghi¹, Laurel J. Trainor^{1,2} (1. Department of Psychology, Neuroscience, and Behavior, McMaster University (Canada), 2. McMaster Institute of Music and the Mind (Canada))

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*Naoya Tachibana¹, Yuko Yotsumoto¹ (1. University of Tokyo (Japan))

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*Shosuke Nishimoto¹ (1. The University of Tokyo (Japan))

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Simulated Gravitational Physics Shapes Time Perception in Virtual Reality

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*Antonio Criscuolo¹, Michael Schwartze¹, Sonja Kotz^{1,2} (1. Maastricht University (Netherlands), 2. Max Planck Institute for Human Cognitive and Brain Sciences (Germany))

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*Christian A. Kell¹, Christina Nissen¹ (1. Goethe University (Germany))

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*Fabrizio Doricchi^{1,2}, Sara Lo Presti^{1,2}, Stefano Lasaponara^{1,2}, Massimo Silvetti³ (1. Universita' La Sapienza - Roma (Italy), 2. Fondazione Santa Lucia IRCCS - Roma (Italy), 3. Institute of Cognitive Sciences and Technologies, National Research Council (CNR) - Italy (Italy))

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*Kyuto Uno¹, Kaoru Amano¹ (1. The University of Tokyo (Japan))

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*Khaled Bagh¹, Christoph Kayser¹, Amir Jahanian Najafabadi¹ (1. Bielefeld University (Germany))

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Perceptual timing precision in complex sound sequences is shaped by context-target similarity

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Sensory-motor mirror neurons in the basal ganglia support temporally precise song imitation in Bengalese finches.

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Vocal timing and social affiliation: A comparative study in rats of same and different strains.

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[P3-40]

Tracking vocal turn-taking and inter-brains synchrony in human interactions

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Perceiving Time in Sleep: Links between Misperception, REM Sleep, and Depressivity in Insomnia

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Subjective time perception is a crucial aspect of conscious experience, including during sleep. In individuals with insomnia, distortions in temporal estimation often manifest as sleep misperception—a mismatch between perceived and objectively measured sleep duration. This exploratory correlational study investigated two potential contributors to time misperception in insomnia: (1) the amount of rapid eye movement (REM) sleep, a stage associated with emotional regulation, and (2) subjective levels of depressivity, which have been linked to both insomnia and altered temporal experience. A total of 202 patients diagnosed with insomnia underwent overnight polysomnography at the National Institute of Mental Health (Czech Republic) between 2017 and 2024. Subjective sleep estimates and depressive symptoms (BDI-II) were assessed alongside objective sleep parameters. Sleep misperception was calculated as the difference between self-reported and measured total sleep time. The results showed no significant association between REM sleep and sleep misperception ($r = 0.091$, $p = 0.103$). However, a weak but significant positive correlation was found between sleep misperception and depressive symptom severity ($r = 0.154$, $p = 0.029$). These findings suggest that distorted time perception during sleep may be more strongly influenced by affective and cognitive factors than by REM-related physiology. To further investigate the neurophysiological basis of this phenomenon, we are conducting follow-up analyses of sleep microstructure. Preliminary results focusing on potential electrophysiological markers of time misperception in insomnia, will also be presented. Supported by ERDF-Project Brain dynamics, No. CZ.02.01.01/00/ 22_008/00046 43 and by the Charles University fund Cooperatio 38 - Neurosciences.

Keywords: time perception, sleep misperception, REM sleep, depressivity, insomnia

Implicit, but not explicit, timing is perturbed in schizophrenia

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Individuals with schizophrenia (SZ) have difficulty estimating periods of time in the peri-second range. However, it remains unclear whether these difficulties index a specific problem in representing time or are a secondary consequence of their more general cognitive disturbance. To address this question, we compared explicit (temporal generalisation) and implicit (temporal expectation) measures of timing in 13 individuals with SZ to that of 29 age-matched controls. In both tasks, the reference interval was 600ms and test intervals varied from 240 to 960ms. In the explicit task, the reference interval was presented on every trial and participants judged whether the variable test interval was the same or different to the reference. In the implicit timing task, participants had to simply respond as quickly as possible to the second of the two stimuli delineating the variable interval. Importantly, the 600ms test interval was four times more probable than the six shorter or longer intervals, which were themselves equally probable. Task order was counterbalanced across participants. Results showed that in the explicit timing task, as expected, the proportion of “same” responses was maximal for the 600ms interval and gradually decreased for increasingly shorter or longer test intervals in an inverted U-shape profile. Correspondingly, in the implicit timing task, mean RT was fastest for the 600ms interval and became gradually slower for shorter or longer intervals in a U-shaped profile. Moreover, analyses revealed that individuals with SZ were as accurate and precise as healthy controls on our explicit timing task in which the reference interval was presented on every trial. By contrast, in the implicit task individuals with SZ significantly overestimated the reference interval compared with healthy controls. This task dissociation suggests that explicit timing in SZ could, in fact, be intact. However, the temporal priors that are formed from temporally predictable information, and used to guide performance in the implicit task, appear to be distorted in individuals with SZ.

Keywords: temporal prediction, interval duration, duration estimation, foreperiod, statistical learning

A Deep Reinforcement Learning Approach to Modeling Rat Behavior in Peak Interval Procedure

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Time estimation is an important concept of adaptive behavior. Most studies focus on utilizing Peak Interval Procedures or Time Bisection Tasks, commonly done utilizing animal models. While animal models may accurately represent biological features, they come with ethical and economical caveats, also being time-consuming. In this study, we intend to generate a computational model to simulate the behavior of rats in Peak Interval Procedures with the objective of providing a replicable and low-cost alternative to running the same experiment on actual animals.

The proposed process utilizes deep reinforcement learning to generate agents that replicate previous empirical data from real rats in Peak Interval Procedures, aiming to achieve a similar Gaussian-like distribution with a peak centered around a 30-second target interval. Agents will be trained using reinforced fixed intervals, and evaluated after each training epoch in fifteen non-reinforced Peak Interval Procedure trials, until achieving results similar to the empirical data; at that point, model weights will be stored. The training process will take into account the configuration of the operant box and penalizations for energy expense upon any action not providing reinforcement.

We expect the model to replicate the characteristic peak in responding around the target interval and to generalize across different durations with adequate training. Beyond its theoretical relevance, this solution may offer an ethical and economic advantage: reducing the number of animals used in experimental settings. This work represents a step toward integrating computational intelligence with animal models in behavioral analysis for timing.

Keywords: Timing, Neural Networks, Peak Interval Procedure, Computational Modeling, Animal Behavior Simulation

Complex impact of stimulus envelope on motor synchronization to sound

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The human brain tracks temporal regularities in acoustic signals faithfully. Recent neuroimaging studies have shown complex modulations of synchronized neural activities to the shape of stimulus envelopes. How to connect neural responses to different envelope shapes with listeners' perceptual ability to synchronize to acoustic rhythms requires further characterization. Here, we examine motor and sensory synchronization to noise stimuli with periodic amplitude modulations (AM) in human participants. We used three envelope shapes that varied in the sharpness of amplitude onset. In a synchronous motor finger-tapping task, we show that participants more consistently align their taps to the same phase of stimulus envelope when listening to stimuli with sharp onsets than to those with gradual onsets. This effect is replicated in a sensory synchronization task, suggesting a sensory basis for the facilitated phase alignment to sharp-onset stimuli. Surprisingly, despite less consistent tap alignments to the envelope of gradual-onset stimuli, participants are equally effective in extracting the rate of amplitude modulation from both sharp and gradual-onset stimuli, and they tapped consistently at that rate alongside the acoustic input. This result demonstrates that robust tracking of the rate of acoustic periodicity is achievable without the presence of sharp acoustic edges or consistent phase alignment to stimulus envelope. Our findings are consistent with assuming distinct processes for phase and rate tracking during sensorimotor synchronization. These processes are most likely underpinned by different neural mechanisms whose relative strengths are modulated by specific temporal dynamics of stimulus envelope characteristics.

Keywords: sensorimotor synchronization, audition, envelope tracking, acoustic landmarks, onset

Two topological axes for temporo-spatial processing in visuomotor control

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In visuomotor control, the right hemisphere has been associated with visuospatial, and the left hemisphere with visuotemporal processing. In right-handed people, asymmetric bimanual tasks result in a preferred use of the left hand for spatial processing and of the right hand for temporal processing. It is unclear, how the two specialized cerebral hemispheres interact with each other when task to hand arrangements respect or do not respect hemispheric processing preferences.

We thus investigated interhemispheric interactions in the cortical visuomotor network in right-handed participants during asymmetric bimanual isometric movements, using magnetoencephalography. The task involved spatially and temporally challenging visuomotor tracking with one hand and a precisely timed ballistic grip without spatial control demands with the other creating a dual task scenario with either an optimal or a non-optimal task to hand assignment.

When the right hand performed the ballistic grip while the left hand performed visuomotor tracking (optimal condition), preparatory interhemispheric broadband partial directed coherence from left premotor areas to right visuomotor regions were stronger compared to the non-optimal condition. In contrast, the non-optimal condition showed stronger preparatory interhemispheric connectivity from right inferior parietal cortex to the left hemispheric visuomotor network.

Our results indicate that the dual task problem is solved by cooperative interactions between specialized cerebral hemispheres with, both, a left-right and a rostro-caudal gradient for temporo-spatial processing.

Keywords: visuomotor timing, visuospatial processing, interhemispheric interactions, hemispheric specialization

Entrainment in Low- and High-Level Ventral Visual Regions Does Not Affect Temporal Overestimations

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Temporal illusions are intriguing yet informative glitches in our otherwise precisely functioning perception of time. One instance of such temporal illusions is our consistent tendency to overestimate flickering intervals (Kanai et al., 2006), a phenomenon known as flicker-induced time dilation (FITD). A decade of research has boiled down to two major hypotheses explaining this temporal distortion: subjective salience (Herbst et al., 2013) and neural entrainment (Hashimoto & Yotsumoto, 2018). Focusing on steady-state evoked potentials (SSVEPs)—neural responses to the regularity of flickers—evidence supporting the neural entrainment hypothesis has been inconsistent (Li et al., 2020). In this study, we employed a combination of luminance-based and semantic flickers (Koenig-Robert & VanRullen, 2013) to explore whether the cortical location of SSVEPs across the visual hierarchy could help explain the inconsistency between FITD and the entrainment hypothesis. While EEG results indicated a distinct pattern of activation in the parieto-occipital regions, the size of the temporal illusion did not vary across conditions. More importantly, the FITD magnitude in flickering conditions (luminance, semantic, and combined flickers) was comparable to the control scramble condition. This latter finding presents a fundamental challenge for time perception theories explaining temporal illusions and suggests a need to revisit the quiddity of FITD.

Keywords: Neural Entrainment, vision, time dilation, flicker

Top-Down Control of Alpha-Band Phase as a Mechanism of Interval Temporal Prediction: Direct Test and Preliminary Evidence

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The brain is able to use cue-interval associations to increase perceptual sensitivity at a specific moment in time, yet the underlying neural mechanisms are still being unraveled. Previous studies on visual perception in non-timing contexts have reported perceptual benefits at specific phases of occipital alpha-band activity. Moreover, exposure to 10 Hz sensory rhythms entrains alpha oscillations to phase-align to on-beat times. However, whether the alpha phase can be adjusted to align with the interval-based predicted target moment, without preceding entrainment, is highly debated. Here, we investigate this by presenting challenging visual discrimination targets at fully predictable intervals that differ in length by half an alpha cycle (800 or 850ms). Top-down control over the alpha-band phase should manifest in phase opposition between the two conditions in a pre-target time window. To examine whether phase inversion depends on temporal sensitivity, we assessed participants'

Just-Noticable-Difference (JND) in a temporal discrimination task. In our preliminary data (N=14), alpha phase appears to be correlated with visual discrimination performance, replicating previous results from non-timing paradigms. This suggests a perceptual benefit could be gained by consistent alignment of phase. However, the preliminary data provides only partial evidence of phase inversion. We observe a substantial shift in the distribution of phase differences across participants relative to a uniform chance model towards a phase opposition model, but only a trend for increase in group-averaged mean phase difference relative to chance level. Surprisingly, we found no correlation between the degree of phase opposition and the JND or alpha amplitude. Additionally, in contrast to previous studies, pre-target intertrial phase concentration is low, calling into question the robustness of this mechanism. Future work should study the modulating factors within and across participants

Keywords: temporal attention, alpha phase, interval timing, EEG, visual perception

Aging effect on temporal processing: an ongoing study on retrospective timing and spontaneous oscillatory bursts.

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In most daily-life activities, our attention is not explicitly oriented toward the temporal dimension of the environment, and we mainly rely on retrospective estimates of time passage. As our sense of time undergoes profound changes with advancing age, we investigated age-related cognitive and neural changes in retrospective duration estimates. To this end, participants estimated the duration after the task, without prior knowledge that time would be relevant, thus relying on a memory-based reconstruction of past events. We compared the EEG oscillatory activity of 40 young (aged 20–35) and 40 older (aged 60–80) healthy adults during a 4-minute rest, followed by a retrospective time estimate (rTE) and cognitive assessment. Building on prior findings that alpha (α : 8–12 Hz) burst activity correlates with rTE in young adults (Azizi et al., 2023), we used a cycle-by-cycle analysis (Cole & Voytek, 2019) to replicate and extend these results to theta (θ : 4–8 Hz) to account for the age-related slowing of neural activity (Courtney & Hinault, 2021). Preliminary results ($N = 48$, including 22 older adults) revealed that while both groups showed similar behavioral estimates, α -burst activity was significantly lower in young adults relative to older adults ($F(1,46) = 4.67$, $p = .036$), but not for theta ($p = .29$). Interestingly, rTE was positively correlated with working memory (N-Back: $r = .33$, $p = .030$) and associative memory (Fast Mapping recall: $r = .36$, $p = .015$) performance. However, no significant correlation was observed between rTE and alpha or theta bursts. Ongoing data collection and analysis of intracranial EEG will help refine these trends at a finer scale. These findings offer a new approach to investigating temporal processing changes with advancing age. Timing, often overlooked, is deeply intertwined with cognition. Understanding its neural underpinnings may thus provide a unique window into age-related changes.

Keywords: Timing, Retrospective, EEG, Aging, Burst

Neural Oscillatory Entrainment in Non-Deterministic Continuous Environments, decoupled from Bayesian Interval Learning

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Predicting the timing of events in continuous, dynamic environments is essential for efficient interaction. In deterministic contexts this is putatively mediated by Oscillatory Entrainment (OE) to the rhythm, and reflected neurally in low-frequency phase alignment, buildup of ramping activity before target, and modulation of target-evoked responses. However, real-world contexts often lack deterministic regularities (e.g., speech). It remains unclear whether and when OE mechanisms engage in non-deterministic continuous streams, and if they can operate separately from distributional learning (DL) processes previously found in uncertain isolated interval conditions. Here, we combined computational modeling of OE (using a simple harmonic coupled oscillator) and DL (using an ideal Bayesian observer) with human EEG recording. We created continuous streams with low (25%) or high (50%) variability, which led to distinct predicted timepoints from the two models. Participants completed a speeded response task with targets at predicted timepoints for each model, as well as intermediate and late timepoints to control for hazard effects. Behaviorally, reaction times were reduced in the 25% relative to 50% condition, selectively for the OE-aligned targets, despite pronounced hazard effect on response times. Neurally, OE-aligned targets elicited lower P3 amplitudes in the 25% relative to 50% condition or to DL-aligned targets, indicating less need for updating for OE predictions. Additionally, delta-band inter-trial phase coherence (ITPC) was higher in the 25% condition before OE target time, mirroring observations in isochronous streams. Interestingly, no contingent negative variation (CNV) was observed. These results highlight the role of oscillatory phase alignment as a predictive mechanism even in the absence of explicit preparatory signals and support the selective engagement of OE in non-deterministic contexts with lower variability, while decoupled from Bayesian DL.

Keywords: Temporal Prediction, Neural Mechanisms, Non-Deterministic Environments, Computational Modelling, EEG

Perceived time shapes the course of physical fatigue

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While numerous studies have documented the influence of bodily states on time perception, the reverse relationship has received less attention. Recent findings suggest that some psychophysiological processes, such as physical fatigue, may follow a subjective rather than an objective temporal evolution. However, the underlying neural mechanisms and the role of motivational confounds remain unclear. To investigate whether physical fatigue can be influenced by perceived time, we asked 24 participants to perform 100 isometric knee extensions in four separate sessions. While the rest time between contractions was constant (5s), the real (R) and perceived (P) durations of each contraction were independently manipulated, unbeknownst to the participants. In each session, contraction duration was either short (10s) or long (12s), and the displayed time was either Normal (N) or Biased (B), yielding four counterbalanced conditions: N10 (10s P, 10s R), N12 (12s P, 12s R), B10 (10s P, 12s R), and B12 (12s P, 10s R). Using force and EMG recordings, we showed that the increase in physical fatigue over contractions was larger in N12 compared to N10 and B12, but also B10, in which the real workload was the same as in N12. This finding demonstrates that, irrespective of motivational factors, physical fatigue follows the perceived time when the clock is slowed down, but not when it is accelerated. EEG analyses further revealed significant power differences in theta and beta bands over frontal (but not motor) areas between N10 and N12, with no difference between conditions sharing the same perceived time, hence highlighting a frontal oscillatory dynamic that thoroughly follows the perceived rather than the real time. All in all, our findings suggest a bidirectional relationship between time perception and bodily states: while prior models mostly emphasize how bodily states can affect time perception, our findings show that perceived time can, in turn, shape physiological processes.

Keywords: Time deception, False-clock paradigm, Fatigue, Electroencephalography, Electromyography

Sequential Brain Activity for subsecond-lagged Sensory and Motor events: Investigation using Temporal High-Resolution fMRI at 9.4 Tesla

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Temporal encoding and modulation in the subsecond is essential for visual perception and movement initiation, and relies on coordinated activity of the cerebellum, basal ganglia, and cortical regions. However, current research methods have significant limitations regarding generalizability, spatial- or temporal resolution, especially given the potential role of rapid neural dynamics in deep circuits. Here, we leveraged increased field strengths of 9.4 T to achieve both high temporal resolution (70 ms vol TR) and spatial resolution (1.5 mm isotropic voxel size), using a segmented 2D GRE EPI sequence based on [1], and tested the ability to detect sequential sub-second activations during a visual perception task with 500 ms delayed flickering checkerboard stimuli presented to the left and right lateral visual hemispheres. In the visual perception task the signal in the left and right lateral visual cortices showed periodic temporal behavior, tracking the temporal dynamics of the stimulus. A delay in the onset of the hemodynamic response function (HRF) matching the onset order of the visual stimuli is present at the majority (68 %) of all single trials in most participants, with the best participant having an accuracy of 100 % and the worst of 30 %. The feasibility of high temporal resolution fMRI in humans at 9.4 T to show temporal sequential activation in the visual cortex was shown. This method is currently being used in an ongoing study to investigate the sequential neuronal activation, ramping slope differences, and other neuronal correlates in the primary motor cortex and the supplementary motor area during movement initiation timing across different sub- and suprasedond intervals.

References[1] Stirnberg et al (2021). Magn. Reson. Med.

Keywords: Fast fMRI, Delay encoding, Sequential brain activity

The effect of temporal regularity on neural activity during perceptual and motor timing

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Perceptual and motor timing in the sub-second range are crucial for daily life, and temporal regularity is a key feature, especially in musical contexts. Previous research has shown that, in perceptual timing, regular stimuli are associated with the basal ganglia, whereas irregular stimuli rely on the cerebellum. Although perceptual and motor timing share some common neural bases, including the basal ganglia and cerebellum, distinct brain activations for regular and irregular stimuli in motor timing have not been demonstrated.

We conducted a functional magnetic resonance imaging (fMRI) experiment to compare the effects of temporal regularity on perceptual and motor timing within the same experimental paradigm. Participants performed two tasks with two types of auditory stimuli: regular and irregular sequences consisting of multiple clicks. In the perceptual task, participants judged the duration of the last interval in the sequence by comparing it to the second-to-last interval and pressed one of two buttons to respond. In the motor task, participants pressed a button after the last click to align their button press with the last two clicks in an isochronous manner.

Regarding the task effect, broad areas, including the premotor cortex, supplementary motor area, and cerebellum, were more activated during the perceptual task than the motor task, likely due to the different button-pressing requirements. Regarding the regularity effect, the putamen, a part of the basal ganglia, showed greater activation for regular than irregular stimuli. However, no significant activation was observed for irregular stimuli compared to regular. No interaction was found between task and stimulus regularity.

Although regular stimuli elicited greater activation in the basal ganglia, we found no difference in the regularity effect between perceptual and motor timing on timing-related brain activity.

Keywords: sub-second timing, temporal regularity, auditory, basal ganglia, cerebellum

Time on my hands: Examination of overlapping rhythmic synchronization mechanisms across sensory modalities

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Proper synchronization mechanisms are necessary for maintaining an understanding of our ever-changing environments. The supplementary motor area (SMA) plays a key role in dynamically processing this information to ensure accuracies in time perception when adapting to these changes. Previous literature has reported differences in synchronization optimization across sensory modalities, namely discrepancies in optimal oscillatory processing dependent on modality type and context. Preferred tapping rates, in which tapping synchronization error is minimal, are commonly used to investigate neural synchronization mechanisms across contexts. Numerous studies have demonstrated that preferred tapping rates have higher frequencies for auditory than visual stimuli, though these frequencies range across the literature. Here, we replicate and extend work by Kaya and Henry (2022) by investigating preferred tapping rates across both auditory and visual rhythms ranging from .5 to 3 Hz. The experiment follows a synchronization-continuation design wherein participants are instructed to tap along to either woodblock tones (auditory metronome) or to a circle moving across the vertical plane (visual metronome) on a computer monitor for five beats followed by maintaining that tapping rate in the absence of stimuli for seven beats. Preliminary data ($n = 19$) suggest no difference in preferred tapping rates between auditory and visual modalities, contrary to previous findings. Data collection will continue in a subsequent experiment ($n = 20$) in which participants are instructed to tap in between metronome beats, rather than on-time, in order to explore whether syncopation elicits differences in synchronization mechanisms as shown through shifts in preferred tapping rates.

Keywords: oscillations, SMA, synchronization-continuation, Hz, tapping

Impact of Retrosplenial Cortex Resection on Temporal Estimation in CD1 Mice

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The retrosplenial cortex (RSC), located in the posterior region of the brain, exhibits intricate connections to sensory and cognitive areas and is correlated with memory impairments. The RSC plays a crucial role in forming associative memory, long-term object recognition, navigation, and contextual memory. Recent evidence highlights its involvement in temporal coding, suggesting its participation in episodic memory and tracking temporal intervals during cognitive tasks. Similar to hippocampal time cells, several RSC neurons exhibit activity at specific intervals during delay periods, yet their role in temporal estimation remains unclear. This study employed an experimental model involving anterior RSC resection in adult CD1 mice, utilizing sham-operated animals as controls. Mobility was assessed in an open field, while temporal estimation was measured using a peak procedure. Results indicated that RSC resection did not impair mobility in male or female mice. However, male mice exhibited reduced response rates during the temporal estimation task compared to females, without significant differences in accuracy, precision, or attention across peak, gap, and distractor trials. The diminished response rate in males potentially reflects reduced motivation. Traditionally, the RSC is associated with spatial cognition, memory, and contextual processing. However, its connections to limbic structures might also play a role in motivation, especially in tasks that demand sustained engagement or associative learning.

Keywords: Retrosplenial cortex, Temporal Estimation, Peak procedure, CD1 mouse

Statistical analysis of small-integer ratios in bioacoustics and music

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Rhythmic structure is ubiquitous in human culture as well as in nature, but is hard to capture in all its complexity. One common pattern in human music are temporal intervals whose relative durations can be expressed as small-integer ratios. For example, the durations of a quarter note and an eighth note are related in a 2:1 ratio (Roeske et al., 2020). Recent work has found that the small-integer ratio categories do not just occur in most human musical cultures, but also in a broad range of animal species' vocalizations or behavioral displays. However, biological systems are noisy, and empirically measured intervals rarely form an exact small-integer ratio, and so, statistical methods are necessary to objectively assess whether an observed behavioral intervals approximately conform to a specific integer ratio. We explain a commonly-used approach for assessing the presence of inter ratio categories in temporal sequences, and then mathematically assess whether this leading integer ratio analysis method in behavioral research makes valid statistical and biological assumptions. In particular, we (1) make the temporal properties of empirical ratios explicit, both in general and for the typical use in the literature; (2) show how the choice of ratio formula affects the probability distribution of rhythm ratios and ensuing statistical results; (3) provide guidance on how to carefully consider the assumptions and null hypotheses of the statistical analysis; (4) present a comprehensive methodology to statistically test integer ratios for any null hypothesis of choice. Our observations have implications for both past and future research in music cognition and animal behavior: They suggest how to interpret past findings and provide tools to choose the correct null hypotheses in future empirical work.

Keywords: categorical rhythm, vocalization, timing, meter, statistical assumptions

Rat Model of Schizophrenia: A Comparative Study of NMDA Antagonists Using the Peak Interval Task

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Schizophrenia is often accompanied by disruptions in temporal cognition, which may be linked with impairments in executive functioning and sensory integration. These deficits can be pharmacologically modeled in rodents using NMDA receptor antagonists. In this study, we focused on interval timing using the peak interval (PI) procedure with a 15-second target duration. We trained 24 adult male Long-Evans rats in this task and after completing an extensive learning phase, animals received acute intraperitoneal injections of saline, MK-801 (0.12 mg/kg), PCP (5 mg/kg), or ketamine (10 mg/kg) in a balanced square design over four weeks. While all three antagonists target NMDA receptors, their effect on the behaviour of the tested animals significantly diverged. Linear mixed-effect models revealed that (1) MK-801 significantly increased the peak time ($p = 0.004$) - the mean peak time increased from 15.9 s (saline) to 22.0 s after the administration of MK-801, (2) both MK-801 ($p < 0.001$) and PCP ($p = 0.012$) led to reduced overall response rates in the task. In contrast, ketamine did not produce measurable differences from saline. Interestingly, the shape of the response curve revealed subtle differences between the substances (Kruskal-Wallis test of the kurtosis of the distribution of the lever presses: $H(3) = 7.89$, $p = 0.048$), which calls for further investigation. Our results suggest the PI procedure is a promising tool for assessing schizophrenia-related timing alterations and highlight distinct effects of different NMDA antagonists on temporal processing. The results of our study also suggest that other phenomena, such as impulsivity and addiction may play a role in operant conditioning tasks.

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Keywords: NMDA antagonists, peak interval, schizophrenia, animal model, rat

Strategic use of temporal cues (timing) in reversal learning: A comparative study in CD1 and C57BL/6 mice

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Behavioral flexibility is the ability of humans and non-human animals to adapt to environmental changes by modifying their responses. Outbred CD1 and inbred C57BL/6 mouse strains showed differences in their performance in novelty, spatial learning, and memory tasks. The Midsession Reversal Task (MSR) assesses cognitive flexibility by requiring subjects to adapt to changes in reinforcement contingencies during the middle of a session. However, the performance of mice in MSR is currently unknown. This study analyzes the behavioral flexibility of C57BL/6 and CD1 mice in tasks with fixed (midsession) and variable reversals at 100% or 50% reinforcement probabilities. A fixed reversal with 100% reinforcement (F100) was used in phase one. Phase two involved a variable change with 100% reinforcement (V100). Phase three used a variable reversal with 50% reinforcement. In half of the subjects, phases 1 and 2 were switched to analyze the impact of past outcomes on cognitive flexibility. Our data indicate that CD1 and C57BL/6 mice complete the MSR task and develop a distinct response pattern depending on the phase. Despite past outcomes, CD1 shows an increased proportion of correct responses in phases 1 and 2 compared to C57BL/6 mice. Both mouse strains had similar correct responses in phase 3, in which the predictor of reinforcement was weak (50%). The problem-solving strategy employed by mice in the MSR task and under variable conditions was identified as a combination of win-stay/lose-shift (WSLS) and timing.

Keywords: Behavioral flexibility, midsession reversal task, variable changes, C57BL/6, CD1

Rock with Me: How Social Interaction Shapes Spontaneous Motor Tempo in Baboons' stone rubbing

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Humans have developed particularly advanced rhythmic abilities compared to other animal species, including non-human primates (NHPs), our closest relatives. More specifically, a finding that has sparked growing interest in the scientific community is that NHPs often struggle to temporally synchronize with an external (usually artificial) stimulus. However, the ability to synchronize is essential in social interactions. Several studies suggest synchronization ability may depend on an individual endogenous variable: the spontaneous motor tempo (SMT), which is the spontaneous production of a rhythm in the absence of an external stimulus. SMT in either the lab or the wild remains largely undocumented in NHPs. Out of the 19 Guinea baboons (*Papio papio*) living in their social group in an outdoor park, 17 displayed a naturally rhythmic behavior not yet described in this species: stone rubbing. We manually coded videos of individuals that exhibited stone-rubbing behavior by annotating each action cycle (endpoints of forward and return strokes). Then we extracted inter-movement intervals and calculated movement frequency, to derive an estimate of the SMT specific to each individual. We then investigated the influence of the presence of conspecifics engaged in the same rhythmic stone-rubbing behavior on individual SMT, by comparing solitary *versus* group contexts. Our results reveal that individuals exhibit distinct SMTs, and that these tempos are influenced by the presence of conspecifics. More interestingly, some individuals seem to adjust their rhythmic tempo to their partner's one. Our findings represent the first description of SMT in this primate species and show that baboons' individual natural tempo is flexible and is modulated by social context. Altogether, our results indicate that studying natural behavior in animals could help broaden our understanding of the evolutionary origins of human rhythmic abilities.

Keywords: Rhythms, Non-Human Primates, Ethology, Spontaneous motor tempo, Social interactions

The effect of visual perceptual load on EEG and behavioural measures of sensory time perception in vision and audition

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Despite much evidence that sensory processing of unattended stimuli depends on the level of perceptual load in the attended task, sensory timing (typically concerning sub-second durations) is often considered automatic and independent of attention (e.g. Paton & Buonomano, 2018). We therefore investigated the role of perceptual load in the perception of sub-second time periods. Participants performed a rapid serial visual presentation task under low or high perceptual load (feature vs. conjunction search) and reproduced the duration of either visual targets (250, 450, or 650 ms, Experiment 1) or concurrent auditory tones with post-cued reproduction (500, 700, or 900 ms, Experiments 2–3). The post-cue ensured participants had to track the duration of every tone while performing the primary task (in contrast to only attending to durations of targets in Experiment 1). Results showed that high perceptual load led to shorter reproduced durations, indicating that increased attentional demands in the attended task compressed the perceived durations. EEG revealed that contingent negative variation (CNV) peak amplitudes at central clusters, measured during the perceptual stage (for non-cued intervals), were significantly increased as a function of duration length, but only under low perceptual load. High perceptual load reduced both the overall CNV amplitude and, importantly, also its duration-related gradient. In contrast, auditory N1 amplitudes (peaking at temporal clusters) were unaffected by load (as expected for suprathreshold stimuli, see Molloy et al., 2019). These findings demonstrate a selective effect of perceptual load on the neural correlates of sensory time perception that is not driven by reduced sensory processing of the timing (auditory) stimulus. We discuss these results in relation to current views of the role of attention in sensory timing.

Keywords: Time Perception, Attention, EEG, Neural Sensory Timing, Perceptual Load

Temporal Jitter in Music Reveals Robust Early Stream Formation and Enhanced Attentional Selection via Attention Recruitment

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Auditory scene analysis involves organizing sounds into perceptual streams. Our prior work indicates early, automatic stream formation for music is more robust than for speech. The present study investigated if temporal regularity of stimuli, a key bottom-up feature that differentiates music from speech, affects this early automatic musical stream formation. Participants (N=15) listened to two simultaneous custom-composed polyphonic piano pieces, spatialized via head-related transfer functions. The degree of note onset jitter within pieces was varied. Tasks were to either detect targets in one stream (segregation task) or both streams (integration). We recorded 128-channel electroencephalography (EEG) and used multivariate temporal response functions (mTRFs) to reconstruct the spectral flux of stimuli, comparing two representational models: a Separated model representing independent neural processing of streams and a Combined model representing unified stream processing. Results replicated our previous findings of early stream segregation where the Separated model outperformed the Combined model at an EEG-to-stimulus lag of 62.5–85.9 ms in both tasks. Crucially, no significant interaction occurred between the Separated versus Combined representational models and jitter level in either task, suggesting note onset regularity did not modulate early, automatic stream formation. However, a significant main effect of jitter was observed, suggesting general neural encoding was enhanced for stimuli with higher jitter in both tasks. Furthermore, for the segregation task, higher jitter also enhanced attentional selection of the attended stream, evident even at early processing latencies (39.1–117.2 ms). This suggests greater temporal irregularity, which is cognitively demanding, recruits greater top-down attention when segregating streams. In conclusion, while early, automatic musical stream formation was robust to note onset regularity, increased temporal irregularity (higher jitter) recruited greater processing resources, enhancing general neural encoding and aiding attentional selection in a complex auditory scene.

Keywords: Auditory Scene Analysis, Temporal Response Functions, Jitter, EEG, Attention Decoding

Valence and arousal lengthen time for subsequent neutral events

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Emotional stimuli are typically overestimated compared to neutral stimuli of equal duration. Recent evidence suggests that the emotional states induced by emotional stimuli could also influence the timing of simultaneous neutral events. Since emotional states can outlast their sources and linger, they could also influence the timing of subsequent events. Here, we tested if and how different levels of valence and arousal modulate the timing of subsequent neutral events. To this end, participants performed a temporal bisection task where they learned a short (400 ms) and a long (700 ms) tone duration. Then, they sorted a range of durations by being more similar to the learned short or long duration. Using our custom vibration patterns, we induced different levels of valence and arousal in a task-irrelevant manner just before the onset of tones in the temporal bisection task. We fitted individual psychometric functions to estimate the bisection points (i.e. equal probability of responding short or long) and Weber fractions. We found that the duration of neutral tones was overestimated when they followed a Low Arousal-Pleasant, High Arousal-Pleasant, or High Arousal-Unpleasant vibration compared to a neutral vibration. Moreover, comparing emotional vibrations revealed an interaction between arousal and valence for subsequent timing. Specifically, we found that for low arousal, pleasant vibrations expanded timing more than unpleasant vibrations. However, independent from valence, high arousal vibrations expanded subsequent timing comparably. We observed comparable Weber fractions in emotional and neutral conditions, suggesting that participants maintain an overestimation bias when judging future events. In conclusion, our results draw a nuanced picture of how emotional states can influence the sub-second timing of future independent neutral events.

Keywords: Time perception, Arousal, Valence, Tactile, Auditory

What do the eyes tell us about emotional temporal distortion? An exploratory study

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Emotional states can significantly influence our perception of time. While this effect is often attributed to increased arousal, few studies have directly assessed arousal through physiological measures. The present study explores the intricate relationship between emotion-induced physiological arousal and temporal processing. Specifically, we examined whether arousal variations elicited by negative stimuli were reflected in pupil dynamics, and whether these changes could predict the degree of temporal distortion experienced during emotionally charged events. Forty participants (20 females; age range: 18–25) completed a time reproduction task while viewing images selected from the International Affective Picture System (IAPS), categorized into three conditions based on perceived arousal: neutral, negative-high arousal, and negative-low arousal. Pupil diameter was continuously recorded using the EyeLink 1000 Plus eye-tracking system. Data were analyzed using generalized linear mixed models to evaluate the effects of emotional content on both pupil responses and time perception. Results indicated that more negative images were associated with greater pupil constriction, suggesting a physiological response to emotional intensity. In terms of temporal processing, participants overestimated the duration of negative-high arousal stimuli compared to neutral and negative-low arousal stimuli. In conclusion, these findings highlight the role of emotion-induced physiological arousal—indexed by pupil constriction—in shaping our subjective experience of time. High-arousal negative stimuli, in particular, appear to significantly distort temporal perception.

Keywords: Time Perception, Emotion, Pupillometry, Physiological Arousal

Auditory Object Formation in Temporally Complex Acoustic Scenes

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The auditory system decomposes boundary-less sensory input into meaningful units through Auditory Scene Analysis (Bregman, 1990). Repetition helps listeners segregate overlapping sounds, and identify distinct auditory objects (McDermott et al., 2011). Studies suggest that repeated units in noisy contexts can eventually be perceived as stable auditory objects (Barczak et al., 2018; McDermott et al., 2011), but the behavioral signature of this dynamic process remains largely unexplored.

We investigated this using “tone clouds” —randomly generated clusters of 50-ms tones lacking explicit boundary cues. Repetition strength was manipulated by adjusting the ratio of repeated to regenerated tones, creating a continuum from random to repeated sequences. This formed an auditory analog to motion coherence tasks. To perceive repetition, listeners had to group repeated tones into auditory objects, allowing us to probe the minimal sensory evidence required.

There were two tasks: repetition detection and sensorimotor synchronization (SMS). In detection, participants judged if sequences repeated. We varied unit duration to examine how temporal structure affects this process. In SMS, participants tapped in sync with the repeating pattern, providing a real-time behavioral measure of perceptual organization.

We show sigmoidal performance across repetition levels in both experiments. Auditory object formation depends on repetition strength and longer durations need more evidence. But once repetition is detectable, ~4 cycles are needed to make a judgment, regardless of unit duration. This suggests the evidence is integrated over cycles. In the SMS, sigmoidal curves converge across unit durations, eliminating the interaction effect. Trial progression analysis reveals two stages during object formation: when repetition is detectable, performance gradually builds up before reaching a saturation point, suggesting a categorical perceptual shift in strong repetition conditions, in which the additional evidence no longer enhances performance.

Keywords: auditory perception, repetition detection, auditory objects, sensorimotor synchronization

Effect of Image Compressibility and Internal Model on Time Perception (Data Collection Forthcoming)

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Natural images differ dramatically in their visual complexity (VC), raising the question of how VC affects cognitive processes that depend on visual input. Specifically, low-level sensory features strongly affect perceived duration (Ma et al., 2024), suggesting that VC influences time perception. However, VC remains poorly defined, encompassing both semantic and structural components. To isolate the latter, studies have argued that complex images contain more information, making them harder to compress (Donderi, 2006). Indeed, extracting information is a potential driving force of time perception (Matthews & Meck, 2016), but the role of compressibility in time perception is underexplored, with few exceptions (e.g., Palumbo et al., 2014). Two main problems are: (1) the compressibility of typical stimuli, such as natural scenes (Ma et al., 2024), is hard to control, and (2) compressibility depends on an observer's expectation or internal model of the images, which has thus far been neglected. To overcome these issues, we use synthetic visual textures (SVTs) - binary images with tunable multipoint correlations and compressibility (Victor & Conte, 2012) - and manipulate participants' internal models via a yet-to-start two-alternatives forced choice task. We generate noisy SVTs of one type (e.g., horizontal stripy patterns), which participants must discriminate from noise. Subsequently, using the same (horizontally striped) stimuli, participants must judge if the images are noise or an SVT of a different type (e.g., block-like texture). This reveals how compressible the images are when the observer's internal model is misspecified (square-like) relative to the ground truth (horizontal stripes). We employ this to measure how compressibility affects perceived duration in a reproduction task and hypothesise that more compressible images represent a greater information source, leading to over-reproduction (Matthews & Meck, 2016). This study reveals how structural visual complexity depends on an observer's internal model and how this shapes time perception.

Keywords: time perception, compression, visual complexity, internal state

Reference Frame Effects on Non-Spatial Tactile Decisions: Evaluation with a Drift Diffusion Model

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The present study explores the interaction between egocentric and external reference frames in the context of non-spatial processing, specifically focusing on vibrotactile frequency perception. While previous studies primarily investigated the impact of reference frames on spatial judgments, such as in temporal order judgment with arm crossing (Yamamoto & Kitazawa, 2001), the effects of reference frames on non-spatial processing, including texture and frequency perception, have been largely unexplored. Tactile frequency perception is known to exhibit an assimilation effect, wherein perceived frequency or roughness shifts towards that of a distracting stimulus, even when individuals attempt to ignore it (Kahrimanovic et al., 2009; Kuroki et al., 2017). This effect is particularly pronounced when the presentation of two stimuli is synchronized. Here, we investigated the combined influence of stimulus simultaneity and arm-crossing on tactile frequency perception.

In the experiment, vibrotactile stimuli were presented to the left and right index fingers, and participants identified which finger received the higher frequency. Stimuli were delivered either sequentially or simultaneously, with arms either uncrossed or crossed. Behavioral results revealed that non-spatial vibrotactile frequency perception was impaired not only by the absence of simultaneity but also by arm-crossing. To further examine the underlying decision-making process, we applied the Drift Diffusion Model (DDM) to participants' response time and accuracy data. The modeling revealed that the drift rate—a parameter reflecting the quality of sensory evidence—was significantly reduced in the arm-crossed condition compared to the uncrossed condition.

These results suggest that non-spatial tactile perception is influenced by spatial information, and that reference frames affect not only spatial localization but also early sensory evidence accumulation in non-spatial perceptual decisions.

Keywords: tactile perception, frequency discrimination, arm-crossing, drift diffusion model

Postdictive suppression of visible stimuli in backward masking: Dissociation between initial and postdictive perception

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Timeline theory of perception (Hogendoorn, 2022) proposes that perceptual mechanisms represent not a single timepoint, but a dynamic timeline updated by prediction and postdiction. Inspired by this view, we investigate whether a masked primer in backward masking—a phenomenon where a briefly presented stimulus becomes invisible due to a subsequent mask—might be initially available to conscious perception and later suppressed postdictively.

We conducted two experiments using a modified apparent motion interference paradigm ($n=7$, 560 trials). Apparent motion was induced by presenting two briefly flashed squares in succession, the second of which was sometimes followed by a mask that prevented the perception of apparent motion. A target character ('C' or mirror-reversed 'C') was then presented either in the same or opposite direction relative to the apparent motion.

In Experiment 1, participants performed a speeded two-alternative forced choice (2AFC) task to identify the character, regardless of its location. In the no-mask condition, reaction time (RT) was significantly shorter when the target appeared in the same direction as the apparent motion than in the opposite direction ($p = 0.016$, signed-rank test), with an average RT difference of 22 ms. However, in the mask condition, where the mask disrupted perception of the second square and hence the motion, this RT difference was abolished ($p = 0.93$).

In Experiment 2, participants performed a simpler 2AFC task judging only the location (left or right) of the target, irrespective of its identity. The motion-congruent RT advantage was observed in both no-mask and mask conditions (no-mask: $p = 0.016$; mask: $p = 0.016$). In the no-mask condition, RTs were on average 35 ms faster for targets in the same direction as the apparent motion compared to the opposite direction; in the mask condition, an advantage of 26 ms was observed. Overall, character discrimination required longer RTs than location discrimination.

These results suggest that the masked primer was initially perceived and influenced early responses, but was postdictively erased and no longer influenced slower perceptual reports. Our findings provide behavioral evidence for the postdictive revision of perceptual experience and support the concept of a continuously updated perceptual timeline.

Keywords: Backward masking, Postdiction, Perceptual timeline

Indifference Interval and Central Tendency in Temporal Reproduction: A Comparative Study of Auditory and Visual Modalities

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Temporal processing is influenced not only by objective stimuli duration but also by factors such as stimulus modality and contextual parameters. Auditory stimuli are often perceived as longer and reproduced more accurately than visual ones, possibly due to differences in pacemaker rate or attentional mechanisms. Combined with the tendency to overestimate short durations and underestimate long ones, these modality-driven distortions have prompted researchers to investigate where subjective timing is most accurate within the tested range. This gives rise to the theory of *indifference interval*—the duration that is reproduced most accurately. Some theories suggest this point is constant (2–3 s), while others link it to the geometric mean of the tested range (central tendency), as per Vierordt's law. We examined the effects of stimulus modality and presentation order on time reproduction using intervals from 1.6 to 15 seconds. Participants were assigned to two versions of the task, with one group starting with auditory stimuli and the other with visual stimuli. This design allowed us to compare performance across modalities and assess the role of block order. Our results align more closely with the idea of a constant indifference interval around 2–3 seconds than with predictions based on the geometric mean. Across all conditions, longer intervals (5–15 s) were systematically underestimated. In the auditory modality, shorter durations (1.6–3.2 s) were moderately overestimated, while in the visual modality, short intervals were more accurately reproduced or slightly underestimated. The highest accuracy occurred near 3.2 s, favoring the idea of a fixed indifference interval rather than one based on the geometric mean (~4.9 s). These findings support the view that internal timing relies on a stable temporal reference and that modality-specific timing characteristics are robust, even when the order of presentation is reversed. This work was supported by the Johannes Amos Comenius Programme (OP JAK), project reg. no. CZ.02.01.01/00/23_025/0008715 and by the grant from the Ministry of Health Czech Republic (no. NU 22-04-00526).

Keywords: indifference interval, auditory stimuli, visual stimuli, reproduction

Simulated Gravitational Physics Shapes Time Perception in Virtual Reality

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In this study, we investigate how simulated gravitational conditions affect time perception within a virtual reality environment. Using a within-subjects design, we developed a virtual reality task in which participants actively and passively experienced Earth's gravity, microgravity, and hypergravity. Thirty-seven healthy young adults participated in the experiment, which involved performing a motor action and place a virtual sphere into a chamber while judging whether auditory tones were shorter or longer than a baseline duration under each gravity condition. The results reveal that microgravity significantly distorted time perception, leading to increased perceptual bias and decreased temporal sensitivity. In contrast, hypergravity produced minimal distortion and, in some cases, improved temporal discrimination. These findings support the hypothesis that gravity-related bodily cues influence the perception of time and underscore the utility of VR as a potential tool for cognitive and perceptual research. Though future studies using possibly more realistic virtual environments are also required to substantiate these effects. The implications of this work extend to understanding human perception in altered gravity environments, optimizing performance in space missions, and expanding the role of virtual reality in gravity-based experimentation.

Keywords: Time Perception, Gravitational Physics, Virtual Reality, Tempo Discrimination, Perceptual Bias

Warped videos, twisted time: The cognitive impact of altered playback speeds

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As sped-up content becomes increasingly common in digital media consumption, understanding its cognitive and perceptual implications is essential. This study investigated whether video playback speed affects time and speed perception. Participants watched videos at two speeds (0.5x and 1.5x), followed by tasks assessing temporal reproduction, verbal estimation, reaction time, and subjective speed perception. Results showed that playback speed influences temporal perception and attentional processes: slowed playback was associated with subjective time dilation and better performance in the attentional task, while sped-up playback led to temporal underestimation and increased perceived speed. Both conditions may impair cognitive functioning, with accelerated playback potentially posing greater risks for tasks requiring precise timing and sustained attention.

Keywords: playback speed, time perception, attention, perceived speed

Effects of non-temporal auditory features on timing judgments in healthy adults and cochlear-implant users

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The kappa effect manifests as a perceptual bias in relative onset timing between subsequent events as a function of non-temporal (e.g. spatial) proximity. In the auditory domain, kappa effects have previously been shown for tone sequences, where tones closer in pitch were judged as occurring closer in time than tones farther in pitch. Recently, our lab established an auditory spatial kappa (ASK) effect, where two sounds presented closer in space were judged as relatively closer in time than a third, more distant sound. The present study examined temporal biasing effects of non-temporal cues in healthy aging and individuals with cochlear implants. In one experiment, we tested younger and older adults with normal hearing on ASK tasks with congruent or conflicting pitch and spatial cues. In a second experiment, we tested individuals with single-sided deafness and a cochlear implant in their deaf ear on ASK tasks to evaluate this task as an implicit measure of auditory spatial cue restoration with cochlear implantation. Results will be discussed in terms of effects of healthy aging on temporal and non-temporal auditory feature interactions as well as clinical applications of auditory spatial kappa tasks for individuals with hearing loss and cochlear implants.

Keywords: Time perception, Kappa effect, Auditory timing, Perceptual interactions, Aging

L-Dopa and STN-DBS modulate the neural encoding of rhythmic auditory stimulation in Parkinson's

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In rhythmic auditory stimulation (RAS), temporally regular auditory stimuli (e.g., metronome or music), are utilized to support the precise temporal coordination of motion¹ in people with Parkinson's disease (pwPD). RAS efficacy is typically associated with the switching from an altered internal pacing system to the intact external cueing system. In doing so, RAS is thought to promote the recruitment of the cerebellar-prefrontal network and recalibrate aberrant β -band synchronization in the striato-thalamo-cortical pathway¹, ultimately mirroring effects observed for dopaminergic replacement therapy (levodopa) and deep-brain stimulation (DBS; ²) protocols targeting the subthalamic nucleus (STN). Here we asked: Do levodopa/DBS treatments modulate the neural encoding of RAS? Does everyone respond to levodopa/DBS interventions the same way? Our analyses revealed changes in (i-ii) event-locked neural responses (pre- and post-stimulus β -band, as well as event-related potentials), (iii) excitation / inhibition balance (E/I; aperiodic exponent) and (iv) neural tracking of rhythm (δ -band inter-trial phase coherence) in function of the treatment. Furthermore, we characterize the link between changes in E/I balance and motor symptom severity (UPDRS-III) with levodopa administration. Overall, we demonstrate inter-individual variability and differential effects of levodopa, 8-week and 1-year DBS treatments on the neural encoding of basic sounds and rhythm, raising doubts on whether every individual benefits from combinations of levodopa/DBS and RAS. In doing so, we encourage future multimodal imaging and translational studies to better characterize individual responses to treatments. This is a fundamental step if we aim at tailoring rehabilitation protocols and optimize intervention efficacy.

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Keywords: Parkinson, rhythm, basal ganglia, DBS, dopamine

EEG reveals how space acts as a late heuristic of timekeeping

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Humans rely on spatial metaphors, gestures, and visual tools to represent the passage of time. Nonetheless, it is unclear to what extent space is an inherent component of the brain's representation of time. Here, we combined EEG-behavioural measures in human participants and neural network models of optimal decision-making to show that space is a late compensatory mechanism of time representation recruited when faster non-spatial timekeeping mechanisms are sub-optimally engaged. We leveraged on the STEARC effect, which shows faster recognition of “short” time intervals with responses in the left side of space and faster recognition of “long” intervals with responses in the right side, and on the recent finding that the STEARC is absent when RTs/decisions are fast (Scozia et al., 2023). EEG studies (Vallesi et al., 2011) have identified the correlates of the STEARC in the inter-hemispheric competition for the selection between left vs right manual responses to short/long time intervals, that is reflected in the amplitude of the Lateralized Readiness Potential (LRP). We investigated whether variations in the strength of the STEARC, as a function of RTs speed, are reflected in variations in LRP amplitude. Most important, we examined whether the emergence of the STEARC at slower RTs is preceded by changes in EEG components associated with temporal encoding during, around or immediately after the offset of time intervals. Although these components cannot be retrospectively modulated by the STEARC, changes in their amplitude and latency may reveal early neural precursors of the STEARC. We found that spatial engagement in timekeeping follows the insufficient non-spatial encoding of time intervals, leading to delayed decisions on their length. These findings provide the first clear evidence of when, why, and how the brain recruits spatial mechanisms in the service of temporal processing and demonstrate that non-spatial and spatial timekeeping systems can be dissociated at both behavioural and electrophysiological levels. Scozia et al. (2023) *Cortex* 164, 21–32.
<https://doi.org/10.1016/j.cortex.2023.03.009> Vallesi et al. (2011) *Cortex*, 47(2), 148–156.
<https://doi.org/10.1016/j.cortex.2009.09.005>

Keywords: Time intervals, Space, Stearc Effect, EEG

Lag adaptation and Bayesian calibration in tactile simultaneity perception

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Accurate perception of temporal relations between sensory events is essential for interacting with the environment. Lag adaptation—where repeated exposure to two signals in a fixed order shifts the point of subjective simultaneity (PSS) toward that order—has been robustly observed in vision, audition, and multisensory domains (e.g., Fujisaki et al., 2004). In contrast, tactile studies have reported an opposite effect—Bayesian calibration—where perceived intervals increase following exposure (Miyazaki et al., 2006). Notably, tactile studies have never adopted the canonical lag-adaptation protocol, where participants received stimulus pairs with a constant lag and then judged the simultaneity (SJ) or temporal order (TOJ) of test pairs with SOAs from an unbiased distribution. We introduced this protocol to the tactile modality to test whether the inconsistent results reflect a somatosensory peculiarity or different protocols. Results showed that the PSS shifted toward the adaptation lag in both tasks, revealing “tactile lag adaptation” for the first time. In separate experiments, we reproduced the protocol typical of earlier tactile studies by eliminating the separation between adaptation and test: participants performed SJ or TOJ of tactile pairs with SOAs from biased distributions. This protocol replicated Bayesian calibration, driving the PSS away from the prevalent lag. These findings resolve a long-standing controversy in temporal perception by demonstrating that the direction of aftereffects depends not on sensory modality but on the protocol. Our findings suggest that Bayesian calibration and lag adaptation reflect distinct yet complementary mechanisms; the former implements statistical inference, biasing perception away from frequently encountered delays, while the latter performs a recalibration, aligning perceptual simultaneity with consistent temporal patterns. Both processes appear essential in enabling flexible and context-sensitive temporal perception.

Keywords: Lag adaptation, Bayesian calibration, Simultaneity perception, Timing perception, Tactile

The modulating role of saccadic and oculomotor behavior during a temporal reproduction task

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Visual signals play a crucial role in shaping our subjective experience of time. Brief visual interruptions, such as spontaneous eye blinks, can disrupt perceptual continuity and potentially alter our judgment of time intervals. In this study, we examined the relationship between oculomotor behavior and time judgments in a temporal reproduction task, both with and without visual feedback during the reproduction phase. Our primary focus was on how different aspects of eye movements during the presentation of the temporal reference stimulus influence the reproduced duration of this. A total of 34 participants completed the task while seated 120 cm away from a monitor, with their head position stabilized using a chin rest. Participants were asked to reproduce half the duration of presented time intervals (1600, 1800, 2000, 2200, and 2400 ms) by pressing and holding the spacebar. Eye movements and blinks were recorded using the EyeLink 1000 eye-tracking system. The results show a positive predictive effect of the blink duration percentage of the interval (Adj. Marginal- R^2 : 0.362, Δ Adj. Marginal- R^2 : 0.0222, $p=0.0008$, β : 2.651), in the stimulus and response phases, in pre-test, on the error percentage of the reproduced durations. These findings support the hypothesis that oculomotor behavior contributes to subjective time perception. Blinks may lengthen perceived duration by disrupting temporal integration. Overall, our results highlight the dynamic role of visuomotor behavior in internal timing and underscore the value of eye-tracking measures in the study of time perception.

Keywords: Time perception, eye-tracking, oculomotor behaviour, blinking, fixation, feedback, duration reproduction

Perceptual timing precision in complex sound sequences is shaped by context-target similarity

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Temporal regularities play a crucial role in auditory processing. In complex sounds, such as music and speech, perceptual sensitivity for on-beat events is enhanced, while deviations from expected timing carry important information. To use such temporal information effectively, listeners must evaluate sound onset timing relative to preceding temporal structures –with high perceptual timing precision (PTP). Previous research has shown higher PTP for simple (short risetime) target sounds compared to complex (long risetime) targets. However, the contribution of preceding context acoustics to PTP is unknown. Here, we examined how context acoustics affect PTP. Participants iteratively adjusted the timing of a target sound relative to an isochronous cueing sequence until reaching perceptual isochrony. Experiment 1 (n=21) manipulated cue and target complexity to test whether cue complexity also impairs PTP. Surprisingly, cue–target similarity, rather than cue complexity per se, predicted PTP: when cue and target were identical, PTP was highest –regardless of the sounds’ complexity. Mismatching cues and targets reduced precision. Notably, PTP was lower when complex cues preceded a simple target than vice versa. To further evaluate the role of acoustic similarity, Experiment 2 (n=24) independently manipulated similarity in spectral content and risetime. PTP was reduced when cue and target differed in risetimes, but not when they differed in spectral content. Together, our findings show that perceptual timing precision is sensitive not only to the acoustic properties of the target, but also to preceding contexts. We propose that listeners form temporal templates based on preceding cues, against which target sound timing is evaluated. This reveals a hitherto unknown constraint on perceptual sensitivity to rhythmic sound sequences: effective temporal prediction depends not just on rhythmic structure, but on acoustic continuity between context and target.

Keywords: perceptual timing precision, auditory perception, acoustic context, onset timing, predictive processing

Timing in peripersonal space beyond internal clock model

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Abstract: Peripersonal space refers to the implicit representation of space surrounding body parts, reflecting the physiological specificity of the body and the pragmatic relevance of nearby object perception for action. Studies on peripersonal space often employ the duration bisection task to investigate spatiotemporal interactions. However, the findings of these studies are inconsistent, and their interpretations remain incoherent. To address this issue, I philosophically examine theoretical frameworks underlying both the experimental designs and the interpretation of results. Particularly, I argue that the internal clock model fails to capture the action-guiding role of peripersonal space, and I outline an alternative approach. First, by conceptualising timing as a pure cognitive process, the internal clock model overlooks the temporality of motor processing, which influences both the structure of peripersonal space and the design of duration reproduction task. Second, the plasticity of peripersonal space through tool integration cannot be explained by the two core concepts of the model, namely, attention and the accumulation of paces. In light of this diagnosis, I sketch an alternative framework in which estimated duration is conceived as time for action execution, rather than as the amounts of accumulated paces.

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Keywords: peripersonal space, interval timing, action guiding, internal clock, tool integration

Poster | Other

📅 Sun. Oct 19, 2025 12:45 PM - 2:45 PM JST | Sun. Oct 19, 2025 3:45 AM - 5:45 AM UTC 🏢 MM Hall (KOMCEE-B1)

[P3] Poster: Day 3

[P3-37] Timing in peripersonal space beyond internal clock model

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Keywords : peripersonal space、 interval timing、 action guiding、 internal clock、 tool integration

Peripersonal space refers to the implicit representation of space surrounding body parts, reflecting the physiological specificity of the body and the pragmatic relevance of nearby object perception for action. Studies on peripersonal space often employ the duration bisection task to investigate spatiotemporal interactions. However, the findings of these studies are inconsistent, and their interpretations remain incoherent. To address this issue, I philosophically examine theoretical frameworks underlying both the experimental designs and the interpretation of results. Particularly, I argue that the internal clock model fails to capture the action-guiding role of peripersonal space, and I outline an alternative approach. First, by conceptualising timing as a pure cognitive process, the internal clock model overlooks the temporality of motor processing, which influences both the structure of peripersonal space and the design of duration reproduction task. Second, the plasticity of peripersonal space through tool integration cannot be explained by the two core concepts of the model, namely, attention and the accumulation of paces. In light of this diagnosis, I sketch an alternative framework in which estimated duration is conceived as time for action execution, rather than as the amounts of accumulated paces.

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Poster | Other

📅 Sun. Oct 19, 2025 12:45 PM - 2:45 PM JST | Sun. Oct 19, 2025 3:45 AM - 5:45 AM UTC 🏢 MM Hall (KOMCEE-B1)

[P3] Poster: Day 3

[P3-38] Sensory–motor mirror neurons in the basal ganglia support temporally precise song imitation in Bengalese finches.

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Keywords : songbird、 basal ganglia、 mirror neuron、 imitation

Songbirds learn complex vocalizations, known as songs, by imitating those of adult tutors. These songs consist of syllables arranged in specific sequences with millisecond-level temporal precision. Successful song imitation requires the integration of auditory input from tutors with vocal-motor output to produce self-generated songs. Understanding the neural mechanisms supporting this temporally precise process may provide broader insights into the neural basis of imitation learning. Previous studies have shown that the cortico-basal ganglia circuit is essential for song learning. In the premotor cortical nucleus, some neurons that project to the basal ganglia fire at specific syllable timings not only during singing but also when the bird is listening to its own song. These “sensory–motor mirror neurons” are believed to contribute to song imitation by linking sensory input with motor output: they fire at precisely timed instants within each syllable, thereby supporting temporally precise vocal control. In this study, we examined whether such sensory–motor mirror neurons exist in the basal ganglia and how their properties change throughout song development. Using single-unit recordings in adult Bengalese finches, we identified basal ganglia neurons that exhibited syllable-specific firing both during singing and during passive playback of the bird’s own song. In juveniles, we found sensory–motor mirror neurons that responded to tutor songs as well as self-generated songs. Importantly, the pattern of neural responses shifted as learning progressed: early in development, neurons responded primarily to the tutor’s song, whereas at later stages they responded more strongly to the bird’s own song. These findings suggest that sensory–motor mirror neurons support vocal imitation by dynamically updating their sensory representations from external auditory targets to self-generated vocal behavior as learning progresses.

Poster | Other

📅 Sun. Oct 19, 2025 12:45 PM - 2:45 PM JST | Sun. Oct 19, 2025 3:45 AM - 5:45 AM UTC 🏢 MM Hall (KOMCEE-B1)

[P3] Poster: Day 3

[P3-39] Vocal timing and social affiliation: A comparative study in rats of same and different strains.

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Keywords : rats、 emotional vocalizations、 ultrasonic、 turn-taking

Social animals form close and enduring relationships with others, and such affiliative bonds confer adaptive advantages, including increased reproductive success and reduced stress. However, given the demands of resting and foraging essential for survival, the time available for social interaction is limited. It is therefore assumed that social animals may adopt strategies to minimize the time cost of establishing affiliative relationships—such as preferentially engaging with similar individuals upon first encounter. This study focused on rats, a highly social species that can form colonies exceeding 150 individuals and are known to maintain social networks that favor specific partners. Prior research suggests that rats may prefer individuals of the same strain in their social networks. However, little is known about how social interactions differ within versus between strains. The goal of this study is to elucidate the mechanisms underlying affiliative relationship formation by comparing social interactions between unfamiliar rats of the same and different strains. We used Sprague-Dawley and Long-Evans rats and recorded their behavior and vocalizations under free-ranging conditions. Specifically, we analyzed the number and timing of ultrasonic vocalizations (USVs): 50 kHz USVs, which are typically associated with positive affect, and 22 kHz USVs, which occur in negative or aversive contexts. Our primary hypothesis is that rats will emit more 50 kHz USVs—and show more immediate vocal responses to their partner's calls—during interactions within the same strain compared to interactions between strains, reflecting a preference for socially similar individuals (Work supported by JSPS 23H05428 to KO and JSPS 24KJ0124 to MK).

From slow motion to time lapse –Exploring biases elicited by altered video speed

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While decades of research have significantly advanced our understanding of time perception, the perception of (manipulated) video speed remains a relatively new and underexplored topic. With technological progress, the use of slow motion and time lapse has become ubiquitous in everyday life, offering new opportunities for detailed video analysis. Yet, recent research highlights potential biases in perception and low sensitivity to altered video speed. To examine the extent to which humans can perceive altered video speeds and how these manipulations influence duration perception, we conducted a series of experiments in which participants viewed short video clips at varying speeds. The results demonstrate systematic biases: overestimation of video speed during slow motion and underestimation of video speed when watching time lapse versions, intensifying with greater deviations from the original speed. Additionally, duration estimations varied systematically depending on video speed, insofar that slow motion videos were perceived as shorter in duration than videos at normal or faster speeds, suggesting a recalibration mechanism occurring during or after viewing. Both effects (misperceived video speed and video duration) seem to result in an erroneous “mental backwards calculation” in the attempt to infer the true duration of an event. This results in a distorted sense of elapsed time, which, in turn, typically can influence, for example, how intentional an action is perceived to be. The observed biases have broad implications for both time perception research and for applied contexts, such as legal or sports settings, where judgments are often based on modern video analysis and hence require careful consideration.

Keywords: video speed, slow motion, time lapse, duration, intentionality