Trieste Encounters in Cognitive Sciences (TEX) 2025

Wednesday, June 25, 2025 - Friday, June 27, 2025

SISSA

Book of Abstracts

Contents

Guest Talk / 2

Representing Durations… From Sensory Data to Magnitude?

Author: Virginie van Wassenhove[1]

[1] *Cognitive Neuroimaging Unit, INSERM, CEA, Université Paris-Saclay, NeuroSpincenter, 91191 Gif/Yvette, France*

Corresponding Author: virginie.van.wassenhove@gmail.com

Prevailing views of time perception posit that the duration of events, a scalar magnitude, results from the perceptual analysis of sensory data. In a series of behavioral experiments (Lambrechts et al, 2013; Martin et al, 2017) , we showed that when equating task requirements and controlling for evidence accumulation across experimental conditions, duration remains resilient to spatial and numerical interferences. In recent work (Jin et al., submitted), we combined ACT-R encoding model and EEG decoding to show a dissociation between sensory evidence accumulation and duration estimation. We also showed that working memory maintains duration in storage but does not directly contribute to timing processes (Herbst et al. 2025; submitted; Shen et al. , in prep). Last, I'll present evidence questioning the automaticity of duration encoding (Nédélec & van Wassenhove, in prep). Altogether, these findings suggest a reevaluation of the computational goals of time perception.

Guest Talk / 3

Differential Utilization of a Hippocampal Learning Strategy as a Source of Individual Variability and Psychiatric Risk Gene Phenotype

Author: David Kastner[1]

[1] *Department of Psychiatry and Behavioral Sciences University of California, San Francisco San Francisco, CA 94143-0518, USA*

Inter-animal variability is a common aspect of behavior; however, we have limited understanding of its causes. Part of the challenge comes from the difficulty of characterizing the behavior of individual animals. I will present on the way individual rats learn a spatial alternation behavior. We find that lesioning the hippocampus leads to changes in the way rats learn, likely leading to the use of a different strategy. We then use those different strategies to characterize how individual wild-type rats learn, finding that even with an intact hippocampus some rats utilize the hippocampal lesion learning strategy. Additionally, I will show that this distribution of learning strategies is shifted toward the hippocampal lesion strategy in a population of rats with a mutation in a high-risk autism spectrum disorder risk gene. Taken together, our data leads to the hypothesis that a source of individual variability can be due to the differential utilization of the hippocampus for behavior.

Guest Talk / 4

Inherent Coupling of Perceptual Judgments to Actions in the Mouse Cortex

Author: Michael Sokoletsky[1]

[1] *Department of Neurobiology, Weizmann Institute of Science, Rehovot, Israel*

It's unclear where in the brain perceptual judgments are made and whether this process is independent of any resulting actions. We designed a vibrotactile detection task in which mice flexibly

switched between contingencies to dissociate between perception and action. A cortex-wide optogenetic screen revealed that the premotor cortex is important for perception rather than the ability to lick, while an imaging screen found correlates of the current contingency but no action-independent correlates of perception. Based on these findings, we propose a model in which vibrotactile perceptual judgments are formed in an inherently but flexibly action-coupled manner.

Guest Talk / 5

Motion in Mind: How Timing and Decision Making Are Linked by Body Movements.

Author: Martin Wiener[1]

[1] *Department of Psychology, George Mason University*

A plethora of work links our perception of time to bodily states. How we move determines when we think things happened, how long they lasted, and when they'll happen again. Separately, movements of the body are intrinsically linked to perceptual decisions across animal species and are evident in human performance. For example, humans and animals exhibit so-called "changes of mind" on decision making tasks, where movement towards one choice response abruptly changes to a different one. In this talk, I will outline how movements in humans and rodents can be linked to decision-making and temporal processing, allowing for a "real time" readout of deliberative processes. In the first section, I will discuss how movements can enhance and alter decision processes during timing, linking them to distinct components of drift diffusion models and demonstrating their effectiveness at explaining differences in individuals with ADHD. In the second section, I will present modeling and EEG evidence explaining how changes of mind can occur in timing tasks, where time itself is the variable to be encoded. Altogether, the findings support a parallel process of timing and decision-making that each inform the other via movement.

Guest Talk / 6

Towards Choice Engineering

Author: Yonatan Loewenstein[1]

[1] *The Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel; The Alexander Silberman Institute of Life Sciences, Dept. of Cognitive and Brain Sciences and The Federmann Center for the Study of Rationality, The Hebrew University of Jerusalem, Jerusalem, Israel*

Shaping human and animal behavior is both practically and theoretically important. Inspired by engineering's success in natural sciences, we ask whether quantitative models can outperform qualitative psychological principles in this task, a concept we call "choice engineering". To test this, we ran a competition where teams designed reward schedules using either quantitative models or qualitative principles to bias choices in a two-alternative task. Results showed that choice engineering was the most effective method, demonstrating that quantitative models are ready to be used for behavior shaping. Additionally, choice engineering offers a novel way to compare cognitive models, beyond traditional statistical methods.

Contributed Talk / 7

Perceptual Compression of Evidence in Intuitive Model Selection

Authors: Francesco Guido Rinaldi[1]; Eugenio Piasini[1]

[1] *International School for Advanced Studies (SISSA), Trieste, Italy*

Corresponding Authors: frinaldi@sissa.it, epiasini@sissa.it

In order to survive, animals constantly face decisions between competing interpretations for noisy and sparse sensory data. In statistics this problem, known as model selection (MS), is typically tackled by balancing a model's goodness-of-fit with a penalty for its complexity. A similar preference for simpler models—a concept known as simplicity bias—has been observed in humans (Gershman & Niv, 2013; Genewein & Braun, 2014). Moreover, human MS strategies have been quantitatively described as a linear combination of the models Maximum Log-Likelihood (L) and terms penalizing model complexity, such as its number of parameters or dimensionality (D) (Balasubramanian, 1997; Piasini et al., 2025). To investigate how the dependence of human behavior on L and D changes with the amount of available data (N), we designed an experiment where 100 naïve participants had to infer the number of hidden generative sources in noisy datasets of variable size. In most theoretical MS frameworks the log-likelihood L (the weight of goodness-of-fit to sensory evidence) grows linearly with N, eventually outweighing D. Our analyses show that the balance between L and D in human strategies changes as well, favoring L as more data becomes available. However, the weighting of the likelihood exhibits sublinear rather than linear growth in N, resembling a logarithm. This observed compressive scaling closely aligns with the well-established sublinear perception of numerosity (Krueger, 1984). The presence of this nonlinearity suggests that intuitive MS potentially leverages lower-level cognitive processes. The departure from ideal normative behavior might therefore arise not from a fundamentally different strategy, but from limitations due to the repurposing of elementary cognitive functions.

Contributed Talk / 8

Integration of Sensory Evidence With Reward History in Sequential Decision Making in Humans and Rats

Authors: Eugenio Piasini[1]; Maria Ravera[2]; Mathew Diamond[2]; Monica Paoletti[3]

[1] *Neural Computation Lab, International School for Advanced Studies (SISSA), Trieste, Italy*

[2] *SENSEx Lab, International School for Advanced Studies (SISSA), Trieste, Italy*

[3] *Neural Computation Lab, International School for Advanced Studies (SISSA), Trieste, Italy and SENSEx Lab, International School for Advanced Studies (SISSA), Trieste, Italy*

Corresponding Author: diamond@sissa.it

Throughout our lives, we observe, interact with, and immerse ourselves in the external world through sensory perception. Sensory stimuli are perceived in the context of the history of our past sensory percepts and actions. When performing standard tactile discrimination tasks in a lab setting, animals and humans are influenced by the history of the stimuli they receive. In this context, the history of stimuli has a measurable effect on the participants'decisions, but it is not known whether and how the sensory information may interact with the history of past rewards to influence perception and decision making. To investigate this, we develop a set of Bayesian ideal observer models and analyze them in a Bayesian Data Analysis framework. Our results suggest that subjects integrate the sensory evidence with the reward history in sequential decision making. Specifically, when sensory information is uncertain, or when subjects'sensory acuity is low, observers rely more heavily on the history of past rewards to make choices. In future work, we aim to address questions about the optimality of integration of reward history and sensory evidence, increase environmental volatility and incorporate more model complexity by considering a broader set of models for the history of rewards in order to determine the most suitable version of the model to capture the behavior recorded in ongoing experiments in rats and humans.

Contributed Talk / 9

Perceptual decision making of nonequilibrium fluctuations

Authors: A. Aybüke Durmaz[1]; Yonathan Sarmiento[1]; Gianfranco Fortunato[1]; Debraj Das[2]; Mathew Diamond[1]; Domenica Bueti[1]; Edgar Roldan[2]

[1] *SISSA*

[2] *ICTP*

Corresponding Author: adurmaz@sissa.it

A pedestrian deciding when to cross a busy street must consider not only the average traffic flow but also the fluctuations in the movement of individual cars. Similarly, the perceptual system must handle both local fluctuations in individual elements and the global patterns that emerge from their interactions. To investigate how the brain makes efficient decisions in such nonequilibrium systems —where evidence changes over time—we conducted three experiments with sixty-seven human participants who judged the direction of a particle exhibiting drifted Brownian motion. The entropy production rate extracted from the particle's trajectory served as a measure of noise dynamics.

We found that mean decision time was inversely proportional to the entropy production rate, establishing an analytical approach to predict the amount of time required to extract the signal given stimulus parameters. Moreover, participants required more time than predicted, indicating suboptimal decision times. An evidence integration approach, equipped with a memory time constant, resulted in tighter fits, indicating that participants adjusted their integration time window to stimulus dissipation, favoring the global trajectory of the stimulus over local fluctuations when the stimuli exhibited higher entropy production.

Furthermore, comparisons between blocked and intermixed conditions revealed that environmental stability was directly linked with decision optimality as well as the flexibility in adjusting integration time window. Complementary approaches indicated that decision optimality was linked to (I) memory load, (II) the recency effect, and (III) the ability to detect meaningful statistical cues in the evidence..

Overall, our work shows that providing a detailed model of the physical properties of the stimuli allows for a better characterization of the variables influencing perceptual decision-making, and refines our understanding of the temporal dynamics of efficient evidence integration.

Contributed Talk / 10

Visual-premotor connections in the processing of visual duration

Author: Francesca Bellotti[1]

Co-authors: Luca Tarasi ; Vincenzo Romei [2]; Domenica Bueti [3]

[1] *SISSA*

[2] *Alma Mater - Università di Bologna*

[3] *International School for Advanced Studies (SISSA), Trieste*

Corresponding Authors: bueti@sissa.it, luca.tarasi2@unibo.it, fbellott@sissa.it, vincenzo.romei@unibo.it

Temporal processing relies on a distributed network of brain regions, with evidence indicating a hierarchical organization in which early sensory areas, such as the primary visual cortex (V1), relay information to higher-order regions like the supplementary motor area (SMA). However, the communication between these areas as well as its directionality and timing remain unclear. This study used twin-coil transcranial magnetic stimulation (TMS) and electroencephalography (EEG) to explore V1-SMA interactions during a duration discrimination task. We examined the effect of varying TMS inter-pulse intervals (IPIs) and target order (V1 - SMA vs. SMA - V1) on behavioral measures and neural signatures of temporal processing. Results revealed that TMS disrupted participants sensitivity to temporal differences when was first applied to SMA at stimulus offset and then to V1 0.1

s later. This effect correlated with a change in the quality of duration representation in EEG signal. Furthermore, alpha power predicted criterion scores at long inter-pulse intervals (0.1, 0.15, 0.2 s) in both stimulation orders. Specifically, stronger alpha power was associated with a stricter criterion. Our study provides novel causal evidence on the bidirectional nature of V1-SMA communication in the context of temporal processing, highlighting the role of feedback connections in duration sensory processing and the involvement of alpha oscillations in temporal decision making.

Contributed Talk / 11

Rat classification of visual temporal frequency is affected by the intensity of task-irrelevant auditory stimuli

Authors: Mattia Zanzi[1]; Francesco Guido Rinaldi[1]; Silene Fornasaro[1]; Eugenio Piasini[2]; Davide Zoccolan[None]

[1] *SISSA*

[2] *Neural Computation Lab, International School for Advanced Studies (SISSA), Trieste, Italy*

Corresponding Authors: mzanzi@sissa.it, sfornasa@sissa.it, zoccolan@sissa.it, frinaldi@sissa.it

The brain combines information from multiple sensory modalities to build a consistent representation of the world. The principles by which multimodal stimuli are integrated in cortical hierarchies are well studied, but it is less clear whether and how unimodal inputs systematically shape the processing of signals carried by a different modality. In rodents, for instance, direct connections from primary auditory cortex reach visual cortex, but studies disagree on the impact of these projections on visual cortical processing. Both enhancement and suppression of visually evoked responses by auditory inputs have been reported, as well as sharpening of orientation tuning and improvement in the coding of visual information. Little is known, however, about the functional impact of auditory signals on rodent visual perception. Here we trained a group of rats in a visual temporal frequency (TF) classification task, where the visual stimuli to categorize were paired with simultaneous but task-irrelevant auditory stimuli, to prevent high-level multisensory integration and investigate instead the spontaneous, direct impact of auditory signals on the perception of visual stimuli. Rat classification of visual TF was systematically altered by the presence of sounds, in a way that was determined by sound intensity but not by its temporal modulation. A Bayesian ideal observer model showed that this phenomenon is consistent with an effective compression of the visual perceptual space induced by the auditory inputs, suggesting an important role for inhibition as the key mediator of auditory-visual interactions at the neural representation level.

Contributed Talk / 13

Project 1917: Predictive processing of movie watching

Authors: Floris De Lange[1]; Ingmar de Vries[2]; Moritz Wurm[2]; Tiziano Causin[3]

Co-authors: Christoph Huber-Huber [2]; Eugenio Piasini [4]; Eva Berlot [1]

[1] *Donders institute*

[2] *CIMeC*

[3] *SISSA & CIMeC*

[4] *SISSA*

Corresponding Authors: epiasini@sissa.it, christoph.huberhuber@unitn.it, eva.berlot@gmail.com, tcausin@sissa.it, ingmar.devries@unitn.it, floris.delange@donders.ru.nl, moritz.wurm@unitn.it

When confronted with dynamic and naturalistic visual input, the brain is continuously always trying to predict what's coming next at different temporal scales and levels of feature complexity. Prediction would require stimulus-related features to be represented before their actual occurrence. This is

also reflected in the active decisions that animals make. For example, the position to fixate in order to "foresee"future information. This hypothesis can be tested by measuring the moment in time at which the neural manifold and/or behavior are most aligned with the visual input.
In our MEG experiment, humans are presented with the same movie ("1917") twice. The movie is highly dynamic and perceptually rich. Participants could freely move their eyes across the screen. On top of the predictions that generally occur in naturalistic settings, we expect the second repetition to be anticipated more in advance with respect to the first. A dynamic extension of representational similarity analysis (dRSA) is applied to single out different levels of the predictive processing hierarchy and how they are modulated by stimulus familiarity. dRSA essentially estimates subjects' average predictions or reactions to stimulus features, their strength and latency.
We observe a clear pattern when analyzing frame-wise visual saliency. Preliminary results show that the object-level is better predicted and more in advance with respect to lower-level visual saliency both for gaze behavior, occipital and parietal MEG sensors. As models for the neural data, we (will) use also convolutional neural networks, visual transformers and other artificial neural networks that capture different facets of visual information, like body posture or body motion. Finally, we will include a multimodal neural network that takes as input videos, instead of static images, to investigate the impact of temporal narrative on neural representations and gaze behavior.

Contributed Talk / 14

Temporal Sequences in Working Memory

Authors: Sophie H. Herbst[1]; Virginie van Wassenhove[2]; Yunyun Shen[1]

[1] *CEA, DRF/Joliot, NeuroSpin; INSERM, Cognitive Neuroimaging Unit; CNRS; Université Paris-Saclay, F-91191 Gif/Yvette, France.*

[2] *Cognitive Neuroimaging Unit, INSERM, CEA, Université Paris-Saclay, NeuroSpincenter, 91191 Gif/Yvette, France*

Corresponding Author: virginie.van.wassenhove@gmail.com

Cognition critically relies on both working memory (WM) and temporal information. However, how our brain processes temporal information in WM remains largely unresolved. Previous work using a novel n-item delayed duration reproduction task found that durations can be stored as discrete items in WM (Herbst et al., 2025). Herein, participants were presented with sequences of temporal intervals (items), marked by brief tones. After a retention period, participants reproduced these items. Using this protocol, I will discuss two studies. In the first magnetoencephalography (MEG) study, we investigated the encoding and retention of time intervals in WM, in which we contrasted brain activity as a function of the number of durations in the sequence and the total duration of the sequence. We observed that during the encoding of the temporal sequence, the amplitude of the evoked response to the last tone increased with a smaller number of items and longer sequence duration. Importantly, this amplitude positively correlated with the participants' reproduction of single-item sequences. During the retention interval, we examined how WM load modulated oscillatory power. Our results showed that alpha (8-12 Hz) increased with the number of items, in agreement with unpublished work (Herbst et al., submitted). In the second behavioral study, we asked whether and how these durations in the sequence interfere with each other, investigating the effects of prospective and retrospective cueing on recall of durations. So we added a cue indicating whether one interval in the sequence (first or second) or the full sequence of intervals had to be reproduced. The cue could be presented before (pro-cueing) or after (retro-cueing) the retention period. We found that a primacy effect on reproduction precision only occurs when retro-cueing for a long duration: the reproduced long duration was more precise in the first position.

Overall, remembering a sequence of durations is to some extent similar to other WM content. Our MEG results suggest that evoked responses and oscillatory power are neural signatures of temporal information encoding and maintenance, respectively. Second, we also found a primacy effect of precision. We expect these two studies to help further clarify how the 'when'is processed in the human brain.

Guest Talk / 15

Competing neural races in human frontal cortex shape decision confidence

Author: Alessandro Toso[None]

Decision formation seems to emerge from a competition between populations of neurons encoding the different choice options located in areas of the parietal and frontal cortex. Theoretical insights suggest that this distributed competition may be key for understanding internal states associated with choice behaviour, especially the confidence about decision accuracy. It has previously been challenging to monitor the dynamics of this competition experimentally. Here, we developed an MEG source imaging approach to track competing neural races for decision in human frontal cortex and relate their competition to the dynamics of decision and confidence formation. Our approach demonstrates a unique contribution of both, "winning"and "losing"neural races to confidence and establishes a novel platform for identifying the principles of distributed cognition in the human cortex.

Guest Talk / 16

Engagement states in decision-making

Author: Philippa A. Johnson[1]

[1] *Leiden University*

When analysing data from perceptual decision-making experiments, researchers often assume unrealistic stability of decision strategies over trials. However, decision-making behaviour features significant trial-to-trial variability. One contribution to this variability is transitions between discrete, internal engagement states - our attention may wax and wane over the course of minutes and hours. These states can be identified using hidden Markov models applied to whole session time courses of choices or response times. In my talk, I will discuss the extent to which engagement states are found across species and the role of neuromodulatory activity in causing behavioural state transitions.

Guest Talk / 17

From the Concept of "Cognitive-Type"Local Circuit to the Whole-Brain Mechanism of Decision-Making

Author: Xiao-Jing Wang[1]

[1] *New York University*

I will first introduce a biologically-based local circuit model of decision-making, diving into its dynamical inner working, cross-level understanding and experimentally testable predictions. Then I will cover recent progress using training recurrent neural network models by machine learning and, finally, connectome-based modeling of distributed decision processes in a multiregional cortex.

Guest Talk / 18

Decision, Memory, and Cognitive Representations

Author: Rava Azeredo da Silveira[1]

[1] *University of Basel*

People suffer from a remarkably long list of cognitive biases—systematic deviations from rational information processing and behavior. Moreover, human behavior is often variable, even when an ideal observer would behave in a deterministic fashion. This talk will focus on biases and variability in the context of decision making when decisions rely on memory. In the first part of the talk, I will show that recorded biases, such as over-reaction to news and the recency bias, are natural consequences of imprecision in the update of memorized information following new observations. In the second part of the talk, I will discuss decisions from memory, i.e., situations in which a choice is based on recalling past experience. I will show that cognitive constraints can lead to the overweighting of extreme instances in past experience. In both cases, the results derive from optimizing cognitive processes subject to costs or constraints. Thus, broadly, the talk will put forth a picture in which biases and variability in human behavior reflect optimality under constraints—'resource-rational cognition'—as opposed to mis-specified beliefs or the use of heuristics.

Contributed Talk / 20

Defining a functional hierarchy of millisecond time: from visual stimulus processing to duration perception

Author: Gianfranco Fortunato[1]

[1] *SISSA*

In humans, the neural processing of millisecond time is associated with the activation of a wide range of brain areas and involves different types of neural responses. Unimodal tuning to stimulus duration, for example, has been observed in some of these areas but not in others, and its presence is either inconsistently reported or appears redundant along the cortical hierarchy. Moreover, how this duration tuning supports different functions or perception remains unclear. To address these questions, we measured brain activity with ultra-high field (7T) functional Magnetic Resonance Imaging (fMRI) while participants performed a visual duration discrimination task. Using neuronal-based modeling we estimated unimodal responses to visual durations across a multitude of cortical areas defined with high anatomical precision. In the parietal and premotor cortices, and the caudal portion of the supplementary motor area (SMA), we observed neuronal populations tuned to the full range of presented durations, spatially clustered in well-defined maps. In contrast, in the rostral SMA, inferior frontal cortex, and anterior insula, neuronal units showed duration preferences centered around the mean of the presented duration range. This preference also correlated with the perceptual boundary participants used to solve the task. Differences in preference, spatial clustering, and behavioral correlation suggest distinct functional roles for these cortical areas—ranging from abstract duration representations for readout and task-related goals in the parietal and premotor cortex, to more categorical and subjective representations in the insula and inferior frontal cortex. In line with these hypothesized roles, we also observed distinct patterns of correlation in duration preferences across these cortical regions. Overall, our findings provide a framework for a more comprehensive understanding of the neural circuits and mechanisms underlying duration processing and perception in vision.