Trieste Encounters in Cognitive Sciences: timing and temporal cognition

Monday, June 12, 2017 - Friday, June 16, 2017

SiSSA Main Campus

Scientific Program

Trieste Encounters in Cognitive Sciences: timing and temporal cognition

Programme description

Monday - 12th June 2017

Virginie van Wassenhove

Neural oscillations: time metrics for information processing in the brain

In this lecture, I will discuss different ways in which neural oscillations have been proposed to contribute to timing and temporal cognition. I will highlight some possible pros & cons and uncertainties of existing proposals and draw examples from published work regarding oscillatory components during timing task.

Marshall G. Hussain Shuler

The neural genesis of reward timing

A central function of the brain is the ability to predict the timing of future events of behavioral importance based on past experience. This ability to appreciate the predictive qualities of environmental cues affords a means by which the organism may subsequently inform the timing of future actions, evaluate the relative worth of options, and govern future learning in response to changes in the statistical structure of the environment. By relating predictive neural activity to behavioral outcome, brain reinforcement systems are thought to mediate changes in synaptic efficacy underlying this ability to learn temporal expectations. Thus, understanding the means by which such reinforcement systems encode interval timing is a central question in the field. Exemplifying this process is the phenomenological observation of so called “reward timing activity“ in the primary visual cortex (V1) of rodents, wherein pairing visual stimuli with delayed reward leads to stimulus-specific activity predicting the time of expected reward (Shuler and Bear 2006; Zold and Hussain Shuler 2015). Having modeled how reinforcement signaling can cause a network to learn to produce reward timing activity (Gavornik, Shuler et al. 2009; Huertas, Hussain Shuler et al. 2015), we tested and demonstrated that cholinergic innervation of V1 is necessary (Chubykin, Roach et al. 2013) and sufficient (Liu, Coleman et al. 2015) for cued-interval timing to form. We then show that such activity in V1 is behaviorally-relevant by demonstrating how spiking activity within V1 is predictive of visually-cued timing behavior, and how perturbation of V1 lawfully shifts the behavioral report of an interval’s expiration (Namboodiri, Huertas et al. 2015). Together, these observations advance a general understanding of reinforcement learning, that the cholinergic system can serve as a reinforcement signal, and that V1 can produce intervals informing the timing of visually-cued behaviors.

Chubykin, A. A., E. B. Roach, et al. (2013). "A Cholinergic Mechanism for Reward Timing within Primary Visual Cortex." <u>Neuron</u> **77**(4): 723-35.

Gavornik, J. P., M. G. Shuler, et al. (2009). "Learning reward timing in cortex through reward dependent expression of synaptic plasticity." <u>Proc Natl Acad Sci U S A</u> **106**(16): 6826-31.

Huertas, M. A., M. G. Hussain Shuler, et al. (2015). "A Simple Network Architecture Accounts for Diverse Reward Time Responses in Primary Visual Cortex." <u>The Journal of Neuroscience</u> **35**(37): 12659-12672.

Liu, C. H., J. E. Coleman, et al. (2015). "Selective Activation of a Putative Reinforcement Signal Conditions Cued Interval Timing in Primary Visual Cortex." <u>Curr Biol</u> **25**(12): 1551-61.

Namboodiri, V. M., M. A. Huertas, et al. (2015). "Visually cued action timing in the primary visual cortex." <u>Neuron</u> **86**(1): 319-30.

Shuler, M. G. and M. F. Bear (2006). "Reward Timing in the Primary Visual Cortex." <u>Science</u> **311**(5767): 1606-1609.

Zold, C. L. and M. G. Hussain Shuler (2015). "Theta Oscillations in Visual Cortex Emerge with Experience to Convey Expected Reward Time and Experienced Reward Rate." <u>J Neurosci</u> **35**(26): 9603-14.

Stefano Panzeri

The time scales of neural population coding in sensation and perceptual decisions

The cortex needs to represents information across a wide range of timescales, from the millisecond-scale required to encode sensory stimuli that fluctuate over milliseconds, to the maintenance of information over seconds that is required to implement certain behavioral choices. Do such diverse timescales result mostly from features intrinsic to individual neurons or from activity in neuronal populations? Here we report that population codes can be essential to achieve long coding timescales, and that the properties and time scales of population codes differ between sensory and association cortices. We compared coding for sensory stimuli and behavioral choices in auditory cortex (AC) and posterior parietal cortex (PPC) as mice performed a sound localization task. Auditory stimulus information was strong in AC but weak in PPC, and both regions contained choice information. Although AC and PPC coded information by tiling in time neurons that were transiently informative, the areas had major differences in functional coupling between neurons, measured as activity correlations that could not be explained by task events. Coupling among PPC neurons was strong and extended over long time lags, whereas coupling among AC neurons was weak and short-lived. Stronger coupling in PPC led to a population code with long timescales and a representation of choice that remained consistent for approximately one second. In contrast, AC had a code with rapid fluctuations in stimulus and choice information over hundreds of milliseconds. Our results reveal that population codes differ across cortex and that cross-cell coupling affects the timescale of information coding. This is joint work with Caroline Runyan and Chris Harvey (Harvard Medical School) and Eugenio Piasini (IIT).

Tuesday **-** 13th June 2017

Virginie van Wassenhove

The conscious time arrow in our mind

In this lecture, I will focus on higher cognitive representations of time in the human mind with discussions questioning the notion of a common representation for magnitudes. I will extend the discussion on the uniqueness of time consciousness which resides in the introspective time arrow, namely the active representation of ordinality in the mind.

Marshall G. Hussain Shuler

A general theory of intertemporal decision making and the perception of time

Making decisions that factor the cost of time is fundamental to survival. Yet, while it is readily appreciated that our perception of time is intimately involved in this process, theories regarding intertemporal decision-making and theories regarding time perception are treated, largely, independently. Following a review of select, yet key advances in our understanding of these issues, I will present a new conception unifying the domains of decision-making and time perception (Training-Integrated Maximization of Reinforcement Rate, TIMERR) to provide a better fit to observations and a more parsimonious reckoning of why we make the choices, and thereby perceive time, the way we do (Namboodiri, Mihalas et al. 2014; Namboodiri, Mihalas et al. 2014).

Namboodiri, V., S. Mihalas, Hussain Shuler, M.G. (2014). "Rationalizing decision-making: understanding the cost and perception of time " <u>Timing and Time Perception Reviews</u> **1**(4).

Namboodiri, V. M. K., S. Mihalas, Marton, T., Hussain Shuler, M.G. (2014). "A general theory of intertemporal decision-making and the perception of time." <u>Frontiers in Behavioral Neuroscience</u> **8**(61).

Warrick Roseboom

Adaptive processes in time and timing

Like other sensory dimensions, temporal perception is strongly modulated by recent sensory experience. Different time scales and courses of exposure can be seen to drive processes that support perceptual stability and improve perceptual precision. In this talk I will outline some of the key behavioural results that demonstrate these processes at play, and discuss some of the possible functional benefits. I will also survey recent progress made in behavioural, computational modelling, and neuroimaging studies that are beginning to resolve some of the apparent conflicts in previous results to lead us towards a comprehensive understanding of the adaptive nature of human temporal perception.

Wednesday - 14th June 2017

Warrick Roseboom

Time perception without clocks

Most psychological accounts and models of time perception have focused on a core set of conceptual components thought to be necessary to generate the perception of time. These components generally include a pacemaker/oscillator, an accumulator, and some kind of attention or switch to control their interaction. In this talk I will outline, firstly, why the notion of a pacemaker is fundamentally mistaken, in a way common to many psychological theories. I will then define a new conceptual approach to time perception that doesn’t require any internal clock, pacemaker, or the like – or indeed, any internal ‘representation’ of time itself. Finally, I will outline our progress in implementing this new approach using a novel combination of artificial neural network methods, and demonstrate the performance of this system relative to humans under similar circumstances.

Ayelet Landau

Temporal cognition and neural oscillation - Part I

Physiological neural signatures can entail rhythmic temporal structure. Such patterns have been known and measured, invasively, as well as noninvasively, for almost a century. What is the functional relevance of brain rhythms? What type of neural mechanisms can be supported by brain rhythms? And how might brain rhythms be instrumental in the quest of unraveling the neural signatures of temporal cognition? My talks I will provide a comprehensive introduction to neural oscillations and exemplify their functional relevance and potential to understanding temporal cognition.

Marco Cicchini

Temporal channels as revealed by human psychophysics - Part I

The idea that perceptual timing is subserved by a single clock available to all sensory and cognitive processes is now giving way to the idea that multiple timing mechanisms exist in the brain. In this two lectures, I will bring evidence from vision and multisensory studies that shows how such clocks have very narrow selectivity implying the existence of multiple clocks across sensory systems. In the two lectures, I will outline evidence from adaptation studies, eye movement studies, attentional studies all pointing towards the idea that timing mechanisms are tuned for spatial location and interval duration and stimulus features. Further selective distortions can occur in one modality but not the other. All this evidence challenges the existence of a single clock in favour of multiple clocks strongly embedded within sensory systems. The functional implications of such architecture will also be discussed.

Thursday - 15th June 2017

Ayelet Landau

Temporal cognition and neural oscillation - Part II

Physiological neural signatures can entail rhythmic temporal structure. Such patterns have been known and measured, invasively, as well as noninvasively, for almost a century. What is the functional relevance of brain rhythms? What type of neural mechanisms can be supported by brain rhythms? And how might brain rhythms be instrumental in the quest of unraveling the neural signatures of temporal cognition? My talks I will provide a comprehensive introduction to neural oscillations and exemplify their functional relevance and potential to understanding temporal cognition.

Marco Cicchini

Temporal channels as revealed by human psychophysics - Part II

The idea that perceptual timing is subserved by a single clock available to all sensory and cognitive processes is now giving way to the idea that multiple timing mechanisms exist in the brain. In this two lectures, I will bring evidence from vision and multisensory studies that shows how such clocks have very narrow selectivity implying the existence of multiple clocks across sensory systems. In the two lectures, I will outline evidence from adaptation studies, eye movement studies, attentional studies all pointing towards the idea that timing mechanisms are tuned for spatial location and interval duration and stimulus features. Further selective distortions can occur in one modality but not the other. All this evidence challenges the existence of a single clock in favour of multiple clocks strongly embedded within sensory systems. The functional implications of such architecture will also be discussed.

Hedderik van Rijn

Neural signatures of time... Really?

In this talk, I will discuss a number of findings that are typically taken to be keystone findings in the interval timing literature, and argue that an objective, critical evaluation could only lead to the conclusion that these phenomena measure other aspects of the tasks that we use to assess timing performance.

Friday - 16th June 2017

Hedderik van Rijn

Continuative Timing: A New Theory to Explain Timing in Everyday Life

Most theories in the interval timing field still rely on the foundational ideas proposed in the original pacemaker-accumulator models. In this talk, I will argue that although these theories are highly successful in explaining the empirical results from laboratory experiments, most are based on assumptions that make them unsuited to explain interval timing performance in realistic, ecological settings. After outlining these issues, I will propose the outlines of a new theory that will allow us to explain temporally driven cognitive performance in laboratory and ecological-valid task settings.

Juan Carlos Mendez

Circuits and mechanisms for temporal categorization

Every day we encounter stimuli which we’ve never seen before. To figure out how to interact with them, we compare these stimuli against similar ones stored in our memory, a process known as categorisation. Time is no exception. To study how the brain of human and non-human primates achieves this, we designed a task in which intervals in the millisecond range had to be categorised as either ‘short’ or ‘long’ according to a criterion acquired previously during a brief training phase. Through the use of psychophysical tools, we determined that both species have comparable temporal categorisation abilities, suggesting that they use similar circuits and mechanisms for this task. Candidate brain areas that could be involved include the dorsolateral prefrontal cortex (dlPFC), the pre-supplementary motor area (preSMA), and the cerebellum. Thus, we temporally altered their activity in human volunteers using transcranial magnetic stimulation (TMS) and measured its impact on the performance of the temporal categorisation task. We found that the sensitivity to the passage of time was altered after stimulation of all areas, particularly after that of the dlPFC and the preSMA. However, this was restricted to the categorisation of intervals below 500 ms and was not observed on that of intervals above 900 ms, supporting the notion of separate circuits for the processing of intervals in the milliseconds and seconds ranges. Finally, we recorded the activity of single neurons in the dlPFC and preSMA of two macaques performing the same categorisation tasks, finding neurons that coded for a) the duration of the interval to be categorised, b) the implicit interval which could serve as a limit between categories, c) the category of the interval, and d) the correct or incorrect outcome of the trial. Thus, these areas possess the sufficient information to make decisions based on temporal information.