ISCH Action TD0904
Time In MEntaL activitY: theoretical, behavioral, bioimaging and clinical perspectives (TIMELY)

TIMELY Workshop on the "Psychophysical, Computational, and Neuroscience Models of Time Perception"

Groningen (NL), April 4-8, 2011

Organized by Hedderik van Rijn & Argiro Vatakis

Information, Programme, Activities, & Abstracts

Location: University of Groningen (NL). With respect to travel, it's probably most convenient to fly to Amsterdam Airport (Schiphol, AMS) and take the direct train to Groningen (About 2.5 hrs.). The other option would be to fly to Bremen and take the bus from Bremen to Groningen railway station (3 hrs). The train station, hotel, and university are all at walking distance from each other.

Meeting locations at the University (for details refer to http://tinyurl.com/timelygroningen):

- Monday, all day: "Munting Building, M.00.74"
- Tuesday, 9:00 - 13:00: "Munting Buiding, M.00.74"
- Tuesday, 13:00 - 19:00: "Munting Building, M.01.61" (first floor)
- Wednesday, 9:00 - 18:30: "Munting Building, M.00.74"
- Thursday, 9:00 - 12:00: "Munting Building, M.00.61"
- Thursday, 12:30 - 18:00: "Munting Building, M.00.74"
- Friday, 9:00 - 15:00: "Heymans Building, Hv.04.06".

Monday at 8:30, someone will guide guest from the University Guesthouse to the university buildings.

Participation: Free. All students participating are required to be present for the whole duration of the Training School.

Student Grants: A limited number of students will be admitted to the Training School and will be funded for up to 600 euros (travel and accommodation). Funding can only be provided for students who attend the full training school *and* present a poster during the student poster session on Wednesday. This poster can either focus on already conducted work, or on planned work.

Prospective participants should be at advanced Master, PhD or Post-Doc level and should submit the following documents to argiro.vatakis@gmail.com:

· Curriculum vitae (please specify if you have any EEG experience)
· Statement of purpose (max 1 page)
· Title and Abstract of the poster that will be presented in the student poster session
· A detailed budget
· Whether you prefer a room in the University Guesthouse or arrange for lodging yourself.

Credits: The Training School is kindly co - supported by the Department of Experimental Psychology, University of Groningen, NL.

For more information on the Training School or joining TIMELY: contact Argiro Vatakis at argiro.vatakis@gmail.com or visit www.timely-cost.eu.

Wireless internet is available in all university buildings. Passwords will be provided during the spring school. A manual with instructions on how to set up a connection can be found here:

http://www.rug.nl/cit/doelgroepen/medewerkers/draadloos/handleiding/Gast_howto_EN.pdf

TIMELY Management Structure

Grant Holder	University of Aalborg (DK)
Chair	Dr. Argiro Vatakis (GR)
Vice chair	Dr. Elżbieta Szeląg (PL)
Secretary	Dr. Georgios Papadelis (GR)
Scientific coordinator (Yearly)	Dr. Fred Cummins (IE) Dr. Mark Elliott (IE) Dr. John Wearden (UK) Dr. Dan Zakay (IL)

ACTION GROUP 1 - *Conceptual analysis and measurement of time*

WG1a - Coordinator	Dr. Peter Ohrstrom (DK) & Dr. Anna Eisler (SE)
WG1a - Co-coordinator	Dr. Valtteri Arstila (FI) & Dr. Bruno Molder (EE)
WG1b - Coordinator	Dr. Hedderik Van Rijn (NL)
WG1b - Co-coordinator	Dr. Rolf Ulrich (DE)

ACTION GROUP 2 - *Exploring factors associated with TP variability*

WG2a - Coordinator	Dr. George Dellatolas (FR)
WG2a - Co-coordinator	Dr. Joseph Glicksohn (IL)
WG2b - Coordinator	Dr. Anna Esposito (IT)
WG2b - Co-coordinator	Dr. Maria Giagkou (GR)

ACTION GROUP 3 - *Extending time research to ecologically-valid stimuli*

WG3 - Coordinator	Dr. Armin Kohlrausch (NL)
WG3 - Co-coordinator	Dr. Leon van Noorden (BE)

ACTION GROUP 4 - *Uncovering the neural correlates of TP*

WG4 - Coordinator	Dr. Christine Falter (UK) & Dr. Valerie Doyere (FR)
WG4 - Co-coordinator	Dr. Virginie Van Wassenhove (FR)

DAY 1 – April 4th, 2011

9:00	Coffee & Welcome
	Psychophysical, Computational, and Neuroscience Models of Time Perception **EEG Day 1**
9:00 – 10:30	Introduction to the EEG methodology: Neural origins of the EEG, various patterns of EEG activity, EEG applications By Niko Busch
10:30-11:00	*Coffee Break*
11:00-12:30	EEG recording: the setup, the technical details related to EEG recording By Agnieszka Wykowska
12:30-13:30	*Lunch Break*
13:30-15:30	Hands-on experience with EEG recording: data collection By Niko Busch & Agnieszka Wykowska
15:30-16:00	*Coffee Break*
16:00-17:30	Introduction to the ERP technique: the averaging procedure, overview of ERP components related to particular perceptual and cognitive processes By Agnieszka Wykowska
17:30	*Closing of the Day*
18:30	*Boat tour through the canals of Groningen & Dinner* *(The boat tour is scheduled for Monday, April 4, 18:30, in this boat:* *http://www.rondvaartbedrijfkool.nl/pages/Goldenraand.html and it will last for 1 hour)*

DAY 2 – April 5th, 2011

	Psychophysical, Computational, and Neuroscience Models of Time Perception **EEG Day 2**
9:00-11:00	Hands-on experience with data analysis: Preprocessing and averaging using Brain Vision Analyzer By Agnieszka Wykowska
11:00-11:30	*Coffee Break*
11:30-13:30	Hands-on experience with data analysis: Frequency analysis using Matlab By Niko Busch
13:30-15:00	*Lunch Break*
15:00-17:30	EEG and research on time perception By Warren Meck & Trevor Penney
17:30	*Closing of the Day*

18:00-19:00	*MC Meeting [Closed session for TIMELY MCs]*

DAY 3 – April 6th, 2011

9:00	Coffee & Welcome
Psychophysical, Computational, and Neuroscience Models of Time Perception	
Models of Time Perception Day 1	
9:00-10:30	Modelling human performance on timing tasks with the SET system By John Wearden
10:30-11:00	*Coffee Break*
11:00-13:00	Associative models of animal timing By Jeremy Jozefowiez & Armando Machado
13:00-14:30	*Lunch Break*
14:30-16:30	Neurobiology of time By Warren Meck
16:30-18:30	Student Poster Session & Drinks
20:00	*Dinner*

DAY 4 – April 7th, 2011

9:00	Coffee & Welcome
Psychophysical, Computational, and Neuroscience Models of Time Perception	
Models of Time Perception Day 2	
9:00-10:00	The Attentional Gate Model of prospective duration judgments By Dan Zakay
10:00-10:30	*Coffee Break*
10:30-11:30	Memory For Time: A review of memory processes in time perception By Luke A. Jones
11:30-12:30	Time estimation embedded in a general cognitive architecture By Niels Taatgen & Hedderik van Rijn
12:30-14:00	*Lunch Break*
14:00-14:30	The perception of circadian phase; emergent properties resulting from single cell-cell interactions By Domien Beersma
14:30-15:30	Rhythms and attention By Angel Correa
15:30-16:00	*Coffee Break*

16:00-17:00	A model of interval timing by neural integration By Patrick Simen
17:00-18:00	Optimal temporal risk assessment in humans and rodents By Fuat Balci
18:00	*Closing of the Day*

DAY 5 – April 8th, 2011

9:00	Coffee & Welcome
Psychophysical, Computational, and Neuroscience Models of Time Perception **Computational Modelling of Interval Timing**	
9:00-10:30	Modelling Interval Timing using an Integrated Architecture By Hedderik van Rijn & Niels Taatgen
10:30-11:00	*Coffee Break*
11:00-13:00	Hands-on Lab Session: Creating Simple Interval Timing Models By Hedderik van Rijn, Niels Taatgen, Jelmer Borst, & Trudy Buwalda
13:00-14:00	*Lunch Break*
14:00-15:00	Explaining Complex Phenomena By Hedderik van Rijn & Niels Taatgen
16:00	*Closing of the Day*

Activities & Abstracts

Modelling human performance on timing tasks with the SET system

John Wearden

Keele University

Scalar expectancy theory (SET) with its tripartite structure of clock, memory, and decision mechanisms, offers the theorist much scope to develop models of performance on a range of timing tasks. Given that a theorist can vary the way that the components of the SET system are implemented in models, and can also add additional mechanisms (such as "attention failure" or "random responding"), how can we avoid the charge that the SET models are arbitrary constructions that can be made to fit any data? This talk discusses the development of models of "standard" timing tasks such as temporal generalization and bisection. It illustrates the different ways that such models could have been developed, and discusses empirical tests of the models as well as their general "behaviour". It also shows how the temporal generalization model can be used to fit "exotic" data that seem at first sight not to conform to it. Extensions of what are basically SET-compatible models to situations where data which clearly violate scalar properties, such as verbal estimation and chronometric counting, will also be discussed.

Student Reading

Wearden, J. H. (2004). Decision processes in models of timing. Acta Neurobiol. Exp., 64, 303-17.

Associative models of animal timing

Jeremy Jozefowiez & Armando Machado

Escola de Psicologia, Universidade do Minho

The workshop will be divided into two parts. In the first we introduce the field of interval timing in non-human animals. We will review the various evidences indicating that animals are able to perceive time, the procedures developed to study sensitivity to time, and the main results that have been obtained and which constitute the breeding ground for the various contemporary theories of animal timing. In the second part we will focus on models of timing. The dominant model is without doubt Scalar Expectancy Theory (SET), a cognitive model according to which an internal pacemaker provides the animal with explicit short-term and long-term memory representations of time which are used to determine its behavior. The SET model will be discussed at length in the companion workshop on human timing. Our workshop will focus instead on more recent associative theories of timing according to which behavior is a function of associations between time-dependent states and responding. We will discuss Machado's Learning-to-Time (LeT) model and Jozefowiez, Staddon, & Cerutti's Behavioral Economic Model (BEM). We will contrast the way SET, LeT, and BEM account for the short-term and long-term memories for time as well as for the decision making implicated in timing. We will examine the data sets supporting the models as well as the data sets challenging them. Our workshop should provide the students with a solid knowledge of the basic facts about animal timing, how to quantitatively model them, and how to empirically distinguish among various quantitative formulations.

Student Reading

Machado, A., Malheiro, M. T., & Erlhagen, W. (2009). Learning to time: A perspective. Journal of the Experimental Analysis of Behavior, 92, 423-458.

Neuroanatomy of Interval Timing

Warren Meck

Duke University

The ability of the brain to process time in the seconds-to-minutes range is a fascinating problem given that the basic electrophysiological properties of neurons operate on a msec time scale. Neuropsychological studies of subjects with damage to the basal ganglia have indicated that these structures play an important role in timing and time perception. Parkinson's patients, for example, show evidence of a slowed internal clock and the "coupling" of durations stored in temporal memory when tested off of their dopaminergic medication. These studies have shown that the normal cognitive functions of the basal ganglia are heavily dependent upon dopamine-regulated neuronal firing in the cortex and striatum. Moreover, the electrophysiological properties of medium spiny neurons within the basal ganglia suggest that networks of these cells may serve as a coincidence detector of cortical and thalamic oscillatory/beat frequency input in order to provide the basis for duration discrimination. Recent electrophysiological data obtained from the prefrontal/cingulate cortex and the anterior dorsal striatum indicate that spiny neurons are able to encode specific durations in their firing rate in a "perceptron-like" manner. These findings correspond well with functional neuroimaging data showing activation of cortico-striatal circuits during timing tasks and lend support to striatal beat-frequency models of interval timing. Contributions of other brain areas, including the parietal cortex and cortico-cerebellar networks, will also be considered.
Student Reading

Buhusi, C.V., & Meck, W.H. (2005). What makes us tick? Functional and neural mechanisms of interval timing. Nature Reviews Neuroscience, 6, 755-765.

Coull, J.T., Cheng, R.K., & Meck, W.H. (2011). Neuroanatomical and neurochemical substrates of timing. Neuropsychopharmacology Reviews, 36, 3-25.

Meck, W.H., Penney, T.B., & Pouthas, V. (2008). Cortico-striatal representation of time in animals and humans. Current Opinion in Neurobiology, 18, 145-152.

Wiener, M., Lohoff, F.W., & Coslett, H.B. (2011). Double dissociation of dopamine genes and timing in humans. Journal of Cognitive Neuroscience (doi:10.1162/jocn.2011.21626).

The Attentional gate model of prospective duration judgments

Dan Zakay
Department Of Psychology, Tel Aviv University

Prospective Duration Judgments are best predicted by attentional based models which assume that the duration judgment process relies on attentional resources. The more attentional resources are allocated for the duration judgment process- the higher the resulting estimation will be. The attentional-Gate model (AGM) is a more elaborated model and is an extension of the Set model. It is also using the attentional-gate concept. The AGM model can provide explanations for many of the findings reported in the prospective duration judgments' literature. The model is criticized by other models like the Dynamic Switch model. In the workshop the model, its foundations and empirical work which support it will be presented and discussed. The debate with the dynamic-switch model will be presented.
Student Reading

Zakay, D., & Block, R.A. (2004). Prospective and retrospective duration judgments: An executive-control perspective. Acta Neurobiologiae Experimentalis, 64, 319-328.

Memory For Time: A review of memory processes in time perception

Luke A. Jones

School of Psychological Sciences, University of Manchester

Many manipulations on temporal processing are thought to occur through altering the operation of temporal reference memory. This is the functional component that is responsible for storing the durations of a presented Standard or a time of reinforcement. In this talk I will explore the history of this concept, the way in which it has been used to explain various experimental manipulations, and our current understanding of its operating characteristics. My theoretical approach is through using the information processing model of Scalar Expectancy Theory (SET).

Time estimation embedded in a general cognitive architecture

Niels Taatgen & Hedderik van Rijn

Artificial Intelligence & Experimental Psychology, University of Groningen

Time estimation plays a major role in many cognitive tasks, but is usually studied in relative isolation. As a consequence, many general characteristics of cognition like attention and learning have been incorporated in theories of time estimation specifically tailored to explain particular empirical findings. For example, effects of attention are often explained by an attentional gate or switch that is part of the time estimation model. In my talk I will show that a more general theory of attention and memory derived from the ACT-R cognitive architecture can explain both attentional and memory phenomena, and is also capable of making successful predictions for new experiments.

Student Reading

(Time perception)

Taatgen, N. A., Rijn, H. v., & Anderson, J. R. (2007). An Integrated Theory of Prospective Time Interval Estimation: The Role of Cognition, Attention and Learning. Psychological Review, 114(3), 577-598.

Van Rijn, H. & Taatgen, N.A. (2008). Timing of multiple overlapping time intervals: How many clocks do we have? Acta Psychologica, 129(3), 365-375.

(General ACT-R)

Anderson, J. R. (2007) How Can the Human Mind Occur in the Physical Universe? New York: Oxford University Press.

The perception of circadian phase; emergent properties resulting from simple cell-cell interactions

Domien Beersma

Chronobiology, University of Groningen

Cells in the biological clock of mammals show intervals of electrical activity and rest which alternate with a period of roughly 24 hours. Even cells in isolation show such rhythmicity, but the period varies in a wider interval around 24h. The difference demonstrates that the cells in the tissue interact. To model biological clock behavior we assume that the intervals of rest and activity show normal distributions, both with respect to the variability among cells and to day-to-day variations within cells. We add simple assumptions about cell-cell interactions and about responses to external light. Simulations show that the integrated system can create synchrony between cells; that the distribution of activity of the cells can adjust to seasonal changes in the photoperiod, and that the system (after being entrained to light-dark cycles of different duration, like 23 or 25 hours) shows a kind of memory of these cycles while single cells do not have that capacity.

Student Reading

Beersma, D. G. M., van Bunnik, B. A. D., Hut, R. A., & Daan, S. (2008).Emergence of circadian and photoperiodic system level properties from interactions among pacemaker cells. Journal of Biological Rhythms, 23, 362-373.

Rhythms and attention

Angel Correa

Universidad de Granada

This seminar will review evidence showing the strong influence of rhythms on human performance during attention tasks. The first part will show that rhythms in the milliseconds to seconds range can induce strong temporal expectations, which enhance information processing at multiple levels. The second part will widen the time scale to circadian rhythms, and will focus on how time of day and individual differences in circadian typology (morning-type vs. evening-type) influence attention performance in vigilance tasks.

Student Reading

Correa, A. (2010). Enhancing behavioural performance by visual temporal orienting. In Attention and Time (pgs. 357-370). Oxford: Oxford University Press.
Link to PDF: http://www.ugr.es/~act/paper/10Correa_Nobre-Ch26.pdf

A model of interval timing by neural integration

Patrick Simen

Princeton Neuroscience Institute, Princeton University

Simple assumptions about neural processing lead to a model of interval timing as a temporal integration process, in which a noisy firing-rate representation of time rises linearly on average toward a response threshold over the course of an interval. These assumptions include: that neural spike trains are approximately independent Poisson processes; that correlations among them can be largely cancelled by balancing excitation and inhibition; that neural populations can act as integrators; and that the objective of timed behavior is maximal accuracy and minimal variance. The model accounts for a variety of physiological and behavioral findings, including ramping firing rates between the onset of reward-predicting cues and the receipt of delayed rewards, and universally scale-invariant response time distributions in interval timing tasks. It furthermore makes specific, well-supported predictions about the skewness of these distributions, a feature of timing data that is usually ignored. The model also incorporates a rapid (potentially one-shot) duration-learning procedure. Behavioral data support the learning rule's predictions regarding learning speed in sequences of timed responses. These results suggest that simple, integration-based models should play as prominent a role in interval timing theory as they do in theories of perceptual decision making, and that a common neural mechanism may underlie both types of behavior.

Student Reading

Gibbon, J. (1977). "Scalar expectancy theory and Weber's law in animal timing". Psychological Review, 84: 279-325. [Establishes some of the basic phenomena in interval timing and gives possibly the best-known explanation of them in terms of a stochastic counting model. Focus on the beginning, pp. 279-300.]

Ratcliff, R. and Rouder, J. (1998). "Modeling response times for two-choice decisions". Psychological Science, 9: 347-356. [Shows how effective a drift-diffusion process is in accounting for response times in decision making. Drift-diffusion is a continuous-time version of stochastic counting.]

Seung, H. S., Lee, D., Reis, B. and Tank, D. (2000). "The autapse: a simple illustration of short-term analog memory storage by tuned synaptic feedback". Journal of Computational Neuroscience, 9: 171-185. [Gives one account of how a neural population could act as an integrator, which is equivalent to a counter of discrete pulses.]

Optimal temporal risk assessment in humans and rodents

Fuat Balci

Princeton Neuroscience Institute, Princeton University

Time is an essential aspect of many simple decisions that humans and animals face. Keeping track of time is adaptive because the temporal statistics of the environment often determine the reward earned from these decisions. Evolution appears to have favored a stopwatch-like mechanism that, with high accuracy but limited precision, allows many organisms to time intervals in the seconds-to-minutes range. Importantly, the subjective sense of time that results is sufficiently imprecise that maximizing rewards can require substantial adjustments of behavior in response to this endogenous timing uncertainty (imprecision). Accordingly, reward-maximization in many decisions requires temporal risk assessment. Using tasks that entail different decisions and that impose different time constraints on the reward function, we characterized the temporal risk assessment ability of humans and animals in terms of the degree to which it approaches optimality. We observed that organisms ranging from mice to humans in fact come very close to taking normative account of their endogenous timing uncertainty in decision-making. The approach that we adopt bridges the empirical and theoretical gap between interval timing and decision making literatures, by incorporating the psychophysics of interval timing into the study of reward maximization.

Student Reading

Balci, F., Freestone, D. , & Gallistel, C. R. (2009). Risk assessment in man and mouse. PNAS, 106, 2459-63.

Student Abstracts

1

A preliminary investigation of a computational model of rhythm perception using polyrhythms as stimuli

Vassilis Angelis

The Open University, Music Dept,UK

Different models of rhythm perception have been developed to explain how humans perceive rhythm in music. Here we concentrate on a computational model that employs a neurobiological approach, according to which aspects of rhythm perception could be directly grounded on the dynamics of neural activity (Large et al., 2010). To date, testing on this model has been done mainly by stimulating it with metrical stimuli. The outputs of the model have been utilised to provide potential explanations about certain behaviours encountered in rhythm perception, such as the negative asynchrony (Large, 2008). This poster presents a preliminary investigation of this model using polyrhythmic stimuli. As a basis of the investigation we referred to a couple of experiments by Handel (1984) and Handel & Oshinsky (1981) on human subjects and polyrhythms, in which subjects were asked to tap along with the polyrhythmic stimuli, implicitly leaving them the choice of tapping out either one of the regular streams, or the cross-rhythm, or any other way. We then sought to examine if such kind of preferences would be reflected on the outcomes of the model. In this poster we present the assumptions involved in carrying out this investigation and the obtained results.

References
Handel, S. (1984). "Using Polyrhythms to Study Rhythm." Music Perception 1(4): 465-484.
Handel, S. & Oshinsky, J. S. (1981). "The meter of syncopated auditory polyrhythms." Perception and Psychophysics (30): 1-9.
Large, E. W., Almonte, F. & Velasco, M. (2010). A canonical model for gradient frequency neural networks. Physica D, 239, 905-911.
Large, E. W. (2008). Resonating to musical rhythm: Theory and experiment. In Simon Grondin, (Ed.) The Psychology of Time. West Yorkshire: Emerald.

2

Contextual binding in Schizophrenia: Weakened integration of temporal intersensory information

Wolfgang Tschacher & Claudia Bergomi
University Hospital of Psychiatry, University of Bern, Switzerland

Cognitive coordination is based on binding processes, by which different features and elements referring to an object or event are integrated and coordinated. We have implemented a paradigm of causality perception based on the work of Albert Michotte, in which two identical discs move, from opposite sides of a monitor, steadily toward and then past one another. Their coincidence generates an ambiguous percept of either 'streaming' or 'bouncing', which the subjects (34 schizophrenia patients and 34 controls with mean age 27.9 y) were instructed to report. The latter perception is a marker of the binding processes underlying perceived causality (binding type I). In addition to this visual task, acoustic stimuli were presented at different times during the task (150 ms before and after visual coincidence), which can modulate perceived causality. This modulation by temporally delayed stimuli is viewed as a different type of binding (type II). We show here that type II binding distinguishes schizophrenia-spectrum patients from healthy controls, whereas type I binding does not: Type II binding was generally attenuated in patients. The present findings are in line with studies indicating disturbances in time perception in schizophrenia and they suggest specific markers of disturbances of cognitive coordination functioning in schizophrenia.

3

Generalization of spectral and temporal stimulus features in perceptual learning using a visual-to-auditory sensory substitution device

David John Brown
Queen Mary University, UK

Sensory substitution devices (SSD) convert one type of sensory signal into another, therefore facilitating the everyday functioning in those with a sensory impairment. The software algorithm of one such device, The vOICe (Meijer, 1992), converts visual features (brightness and spatial position) into auditory features (amplitude, pitch, time and stereo panning). Whilst generalized perceptual learning has been demonstrated in sensory substitution the neural correlates of this cross-modal activation are unclear. At a sensory level the output from The vOICe is, in essence, auditory, yet there is evidence that the brain processes these signals in a 'unique' way.
The present experiment will use sonified images to compare the time course of improvement on a trained condition (specific learning) to that of an untrained condition (generalization) in a temporal-interval discrimination task. Comparisons will be made with the auditory perceptual learning literature to evaluate how this multisensory signal is processed. Hypotheses are twofold.

Firstly there will be a temporal 'lag' between specific and generalized learning implying different neural sites of activation for these two processes. Secondly, generalization will be found for temporal as well as spectral features of the stimulus, contrary to what is found in unimodal auditory perception. This will give a unique opportunity to investigate how time perception translates across sensory modalities to give a representation of spatial position.

The research will hopefully provide support for a metamodal perceptual brain based on function rather than specific modality with theories being used to inform training protocols for the use of SSD's

References

Meijer, P.B.L. (1992) An experimental system for auditory image representations. IEEE Transactions on Biomedical Engineering, 39, 112-121.

4

The interplay between time processing and conditional probability in temporal preparation

Mariagrazia Capizzi[1], Nicolas Rochet[2], Ángel Correa[1], Daniel Sanabria[1], & Boris Burle[2]

[1] *Departamento de Psicología Experimental y Fisiología del Comportamiento, Granada, Spain*

[2] *Laboratoire de Neurobiologie de la Cognition, Aix-Marseille Université, CNRS, Marseille, France*

The Temporal information processing is crucial in reaction time tasks that manipulate the time interval (i.e., foreperiod) between warning and reaction stimulus. When foreperiod is constant within a block of trials (fixed-foreperiod design), reaction time gets longer as foreperiod duration increases. In short constant foreperiod trials, time estimation allows participants to synchronize their response readiness to the onset of the reaction stimulus. As the foreperiod gets longer, however, time uncertainty increases reducing participants' preparatory state and thus lengthening reaction time. In contrast, when foreperiod changes randomly within the block (variable-foreperiod design) reaction time gets faster as foreperiod duration increases. An additional mechanism is needed to account for these discrepant findings, i.e. conditional probability. When foreperiod varies randomly from trial to trial, if the event has not yet occurred at the short foreperiod, then the conditional probability of stimulus onset grows with the passage of time enabling participants to optimally prepare to the longest foreperiod as compared to the shortest one. While recent electrophysiological studies have started to unveil the neural substrates of temporal processing in fixed-foreperiod designs (see Burle, Hasbroucq, & Tandonnet, 2010, for a review), very little is know about the interplay between time processing and conditional probability in variable-foreperiod designs. Do they affect the same stage- perceptual, central or motor- of information processing? To address this question, we performed a between- hand choice reaction time task in which participants were to respond by a left- or a right-hand key press to the colour of a stimulus presented after one of two equally-probable foreperiod intervals. While performing the task, both electrophysiological (EEG, 64 channels) and electromyografic (EMG) activity of the muscles involved in response execution were recorded. Our preliminary EMG analysis suggests that, contrary to fixed foreperiod, conditional probability does not affect temporal preparation at the motor level but more likely at higher perceptual/and or decisional levels. Current EEG analysis is in progress in order to decipher the underlying neural substrates.

References

Burlè, B., Tandonnet, C., Hasbroucq, T. (2010). Excitatory and inhibitory motor mechanisms of temporal preparation. In Attention and Time (p. 243-255). A.C. Nobre and J.T. Coull (Eds.). Oxford University Press.

5

Order does matter: Temporal order effects on discrimination performance

Oliver Dyjas

University of Tübingen, Germany

In many psychophysical tasks on time perception, subjects have to discriminate between two successively presented stimuli. Often, one of these stimuli is a standard s and kept constant throughout the experiment. The other stimulus is the comparison c and varies from trial to trial. At the end of each trial, subjects are required to judge which of the two stimuli is longer. Recent psychophysical studies indicate that discrimination performance depends on whether the standard precedes or follows the variable comparison, that is, whether the temporal order of the two stimuli in each trial is <sc> or <cs>, respectively. In particular, discrimination performance suffers when the standard follows rather than precedes the comparison. This phenomenon is known as Type B order effect. Type B order effects contradict classical models of psychophysics. These models assume that comparing two stimuli is based on internal representations of these stimuli and discrimination performance should therefore be independent from the temporal order of the two stimuli. I will present primarily psychophysical results that assessed whether the Type B order effect is context sensitive. Specifically, the experiment compared various conditions in which the order of the two stimuli was fixed within an experimental block or randomized across the trials of a single block. These results will be used to examine the validity of a model which assumes that an internal standard emerges across the trials of an experiment in order to account for the Type B order effect.

6

Influences of sensory feedback delay on duration reproduction

Stephanie Ganzenmueller

Graduate School of Systemic Neuroscience, Ludwig-Maximilians University of Munich, Germany

Sensorimotor feedback delay is known to be a key factor in action. Previous research has shown that humans can adapt in some degree to crossmodal temporal inconsistency as well as to sensorimotor delays. To date, however, still little is known about how feedback delays impact the duration control and the timing of on-going or to-be-performed voluntary action. To investigate how sensory feedback delay changes motor duration control, we injected a fixed onset or offset delay in the subsequent sensory feedback of participants' own action. We adopted an action-based time reproduction paradigm with feedback in a series of experiments. Participants were asked to replicate an auditory (Exp. 1 and 4) or a visual (Exp. 2 and 3) standard duration, by pressing and holding down a button for the same amount of the time. While participants were pressing the button, a feedback stimulus (a tone in Experiment 1 and 3, a LED light in Exp. 2 and 4) was presented. A block of ten trials, in which either the onset or the offset of the feedback was delayed was followed by a block of ten trials with accurate feedback. Such manipulation allows us to examine adaptation after-effects. The results showed that the duration reproduction was overestimated in general when the feedback onset was delayed (almost complete compensation for onset delay was found with the auditory feedback). This overestimation could be seen instantaneous, starting from the first trial of the onset delay condition block. In contrast, the duration reproduction was underestimated when the offset of the auditory feedback was delayed. There was no significant effect of visual offset feedback delay on the duration reproduction. Other than during the onset-manipulation, participants required some time to adapt to the new condition (five trials to the offset delay condition and four trials to re-adapt back to the accurate feedback condition). In Exp. 3 and 4, duration presentation and reproduction were in different modalities. We found a strong underestimation of visual standard durations (Exp. 3) and a strong overestimation of auditory standard durations (Exp. 4), which is in agreement with the literature. Overall our results indicated that participants' motor control of duration reproduction was strongly biased by the feedback modality and feedback delays.

7

Processing of visual temporal information and its relation to psychometric intelligence: Converging evidence for the temporal resolution power hypothesis of intelligence

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According to previous studies there is a well-established functional relationship between temporal resolution power (TRP), assessed by auditory psychophysical timing tasks, and psychometric intelligence. Here we investigated whether the relation between psychometric intelligence and temporal information processing can be also observed in the visual modality. For this purpose, performance on four visual psychophysical timing tasks (duration discrimination with filled and empty intervals, temporal generalization, and rhythm perception) was examined and related to performance on a psychometric test of intelligence. Correlational analyses indicated a reliable positive association between performance on each of the four temporal tasks and psychometric intelligence. Structural equation modeling suggested that performance on the four tasks can be assigned to one latent variable, referred to as TRP, which explained 16.5% of variance of psychometric intelligence. Findings indicate that the functional relationship previously observed between auditory temporal processing and psychometric intelligence can be generalized to the visual modality.

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Neural correlates of music and action: An electrophysiological and behavioral study

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Considering the cogent evidence for shared neural resources between language and music (Koelsch, 2005; Maess, Koelsch, Gunter, & Friederici, 2001), and the plausible link between language and action (Rizzolatti & Arbib, 1998; Tettamanti et al., 2005), an electrophysiological and behavioral study investigated neural overlap between music coupled with actions in an interference paradigm. Five-chord sequences and five images depicting a hand trajectory and object-grasp were presented simultaneously (one chord per image); the in/correctness of the final cadence/grasp was manipulated in a 2 x 2 factorial design, in which either both cadence and grasp were correct (tonic final chord and normal grasp), only the final chord (Neapolitan chord) or only the grip (too large/small for the object) or both were incorrect. This experiment was the first of its kind, and the unprecedented action stimuli elicited a biphasic ERP pattern which likens to evidence of syntactic processing in language (Hahne & Friederici, 1999) and music (Patel, Gibson, Ratner, Besson, & Holcomb, 1998), while the behavioral results yielded a music-action interaction. Though an expected ERP music-action interaction was not found, the similar ERP patterns in the music, language and action domains are promising and encourage investigation of the cross-domain processing of sequential or hierarchical information.

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Coding and predicting the resolution of temporal discrepancies across the senses

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Time is an essential dimension of human experience, yet our understanding of how temporal signals are combined across sensory modalities and coded remains unclear. The aim of the three studies presented is to determine whether temporal cues are combined in (1) the statistically optimal way such as described by the Maximum Likelihood Estimation (MLE) model. (2) to assess whether temporal features such as the onset, or offset of a signal are systematically related to the impulse response functions for the relevant stimuli (3) how the brain adapts to asynchrony between what we see and hear and recalibrates to maintain temporal coincidence of an audiovisual event. In experiment 1: using a 2 interval forced choice (2IFC) procedure observers estimated the duration or time course of events. They indicated which interval was longer, the first or the second. We manipulated the reliability of the auditory signal to provide a diverse weighting scheme for visual and auditory components so that we could test the integration strategy of a statistically optimal observer (MLE) against our empirical bimodal data. We found that for signals of equal weight MLE the model predicts the perceived duration and we get an optimal decrease in the noise in duration estimates. Breaking down perceived duration to the estimation of different time points, i.e. onset, peak amplitude and offset of a Gaussian signal, the second study investigated the type of filter or transfer function that describes the difference in physical and perceived time. We explored whether such perceptual estimates of temporal points (onset, peak amplitude & offset) strongly deviating from physical time, and whether this is consistent across sensory modalities. Participants undertook a temporal order judgment task and estimated onset, peak amplitude and offset of a long Gaussian signal (sigma 150ms) by comparing it with a short spike-like comparison stimulus (sigma 5ms). The stimulus configurations tested were unimodal visual with long Gaussian (V) and short Gaussian signal (v), unimodal auditory (A-a) and crossmodal (A-v, V-a) stimulus randomised within the blocks. Results demonstrate that temporal (PSS) estimates depend on the modality of the long stimulus: Onset PSS for (A-a) & (A-v) occurred earlier than for (A-v) and (V-a). For offset estimates the A-a and A-v conditions were perceived as later than the V-v and V-a configurations. However, peak amplitude estimates produced an amodal pattern with all estimates aligned but perceived earlier than physical peak. For long auditory signals, the perceived duration of the temporal event was overestimated and for long visual signals, was perceived as shortened. Discrimination thresholds were better for the long visual signals than for long auditory signals irrespective of what point in the temporal event was estimated. Such differences can potentially be used to explain illusions such as the flash lag effect and discrepancies in perceived duration across the senses. We quantitatively explain these effects using models of signal processing. In the third experiment looking at recalibration we explored which sensory modality changes as a function of adaptation to asynchrony. We measured response times and our results revealed that RTs to sounds became progressively faster when exposed to visual leading asunchrony or slower in the reverse condition as people's exposure to asynchrony increased, thus providing the first empirical indication that our speeded responses to sounds are influenced by exposure to audiovisual asynchrony. Our results suggest that time is coded in a signal dependent matter but that changes in integration of the temporal information are plastic and can occur online.

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Does the temporal eye blink? Attention influences subjective duration

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As humans lack a sensory organ for the perception of time, our perception of duration is highly influenced by the sensory content of the time interval to be judged. Thereby an important question is to know which perceptual processes can influence our internal time keeping mechanism, hypothetically described as an internal clock sampling pulses in order to estimate time. Different views exist: interval duration could be estimated based on a basic perceptual level, as a function of the number of changes in the underlying input (Brown 1995; Xuan et al., 2007). Alternatively, time estimation could be based on high-level stimulus processing requiring attention (Tse et al., 2004). In order to distinguish between the influences of early and late processes on perceived duration, we applied a well-established paradigm from attention research: the Attentional Blink (Raymond et al., 1992). When presented with a rapid stream of stimuli, subjects often miss the second of two targets presented in close proximity, a lapse that is explained by a bottleneck in attentional processing and has been termed 'attentional blink'. This paradigm allows an experimental separation of stimuli that are completely processed up to reaching consciousness, from stimuli which are only processed on an initial level and hence not reported by the subject (stimuli in the attentional blink). Here we use this clear distinction to study the influence of different levels of stimulus processing on subjective duration. Subjects were shown sequences of letters in a rapid serial visual presentation paradigm and instructed to count the appearance of the letter 'X', which could appear once or twice. After that, they were asked to judge the duration of the each sequence in relation to a standard sequence, which did not contain any target letters. Second, in each trial subjects reported the number of 'X' they had seen. We compared perceived durations based on the number of targets reported.

An additional target in the sequence prolonged the sequence's subjective duration when the target was correctly detected. Sequences containing two targets were hence judged as longer, if the subject also reported both targets. In contrast, if an attentional blink occurred in a sequence (meaning, subjects missed one out of two targets), the sequence was perceived as significantly shorter than the standard. Although we know that targets missed in an attentional blink are processed on a basic level (Dehaene et al., 2006), here they did not influence subjective duration. Our findings argue for a specific influence of higher-level cognitive processes on perceived duration, or – in other words – suggest that the number of changes in visual input does not fully explain the emergence of subjective duration.

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Time perception in schizophrenia

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Time awareness has been found to be disturbed in patients with schizophrenia. As schizophrenia is often linked to the prefrontal cortex, it is perhaps not surprising that schizophrenic patients often also exhibit impairment in working memory. Working memory provides a kind of cognitive workspace in which we can combine current perceptions with past memory, so it is a strong candidate for part of what forms our subjective experience of time. Memory in a broader sense is an obvious prerequisite for temporal awareness, and the formation of episodic memory, which is also impaired in schizophrenia, is key to a prolonged, integrated sense of time. Schizophrenia has recently been described as a breakdown of connectivity, which includes disruption in the temporal aspect of signalling in the brain. Fitting together neural substrates with their functional expression in cognition and behaviour may integrate these aspects of disturbed time perception in schizophrenia.

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Effects of practice on timing accuracy in an interval production task

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One of the major problems that research in timing has to face is that most studies do not take into consideration individual differences that have been proved to have an influence on timing performance. For example, very few studies have explicitly investigated the effects of training on timing performance. In this study we used the isochronous serial interval production (ISIP) task in order to access timing variability. The ISIP task consists of marking regular intervals, whose purpose is to induce the desired interval. The variability of the produced temporal intervals can be divided into local variability (Local) between neighboring intervals, and drift (Drift), fluctuation in tempo over several intervals. We are interested in this millisecond variability because a new line of research is developing that relates timing performance to cognitive functioning and there are many studies which have found high correlations between this variability and intelligence tests. Our purpose is to determine how much training is required to reach an asymptotic level of performance, how much variability that entails and how this interacts with mode of response, and sensory feedback. For this reason we conducted two separate experiments. Experiment 1 focuses on inter-onset intervals and Experiment 2 focuses on the amount of training, mode of response and sensory feedback. The results confirmed our hypotheses that practice enhances the accuracy and reduces variability in a simple timing task, especially when auditory feedback was used. Specifically in the 5th session participants produced the lowest amount of variability. These concerns may not have been critical issues in this area until recently, but after this promising development in timing research (correlations between ISIP variability and cognitive functioning), this raises questions about reliability and validity that are critical for this research area.

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Does CNV amplitude reflect accumulated time? A Failure to Replicate Macar, Vidal, & Casini (1999)

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Numerous studies have shown that contingent negative variation (CNV) measured at frontocentral and parietal-central areas is closely related to interval timing. A highly influential study in this context is the 1999 paper of Macar, Vidal, and Casini: "The supplementary motor area in motor and sensory timing: Evidence from slow brain potential changes". In this paper, trial-to-trial performance-dependent variations in CNV amplitude are presented during a task in which participants had to produce 2.5s intervals. In their study, time production trials were pseudo-experimentally categorized on the basis of the estimated duration as "short" (2.2-2.4s), "correct" (2.4-2.6s) or "long" (2.6-2.8s). The Laplacian-transformed amplitude for the long condition was higher than the amplitude for the short condition, with the correct condition in between. This result has strongly influenced theories on the functional neuroanatomy of interval estimation as it is often quoted as support for the hypothesis that the supplementary motor area reflects the accumulation process.

Here we report two replication studies, both very similar to the original study. In both studies, we failed to replicate the amplitude effects as reported by Macar, Vidal and Casini (1999), regardless of whether analyzed amplitudes were taken directly from monopolar electrodes, or whether they were based on current source density (CSD) transformations. Amplitude differences were however observed as a function of progression over trials: Habituation effects were observed in frontal and fronto-central regions in monopolar and CSD-based analyses in the first study, and in CSD-based analyses in the second study. Given the lack of amplitude effects as a function of the estimated duration, these replication studies either indicate that the CNV effects reported earlier are not particularly strong, or indicate that the CNV amplitude does not serve as an index of trial-to-trial fluctuations in interval timing.

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The effect of motion on time perception using the temporal bisection and temporal generalization paradigms

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This study investigated the effect of motion on time perception. In a Temporal Bisection task, ten participants were exposed to a Short (300 ms) and a Long (700 ms) tone and then classified tones of intermediate duration. In the Temporal Generalization task, ten other participants were exposed to a target 500-ms tone and then judged whether a series of tones (ranging from 300 to 700 ms) were the same as or different from the target. Each task was performed under two conditions, while the participants ran on a treadmill or stood still, with the order counterbalanced within and between subjects. The results suggest that, a) in the bisection task, the stimuli were more often classified as "Long" while running than standing still; b) in the temporal generalization task, there was some evidence that tones longer than the target were underestimated. These results will be discussed in the light of current theories of timing such as Scalar Expectancy Theory (increased pacemaker speed and latency to start timing).

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What's the Time? Are technological advances affecting our temporal judgments?

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At times it is very noticeable that our subjective experience of time is not an accurate portrayal of "real time", as measured by clocks. However, in spite of the seemingly ubiquitous experience of individuals in modern society feeling under more and more time pressure there has been surprisingly little research on what affects our time experience, and how modern technologies are impacting on the individual's temporal judgments. In order to address this issue two experiments were conducted to investigate whether individuals who use more everyday technologies perceive durations differently. In Experiment 1 participants completed the ETUQ questionnaire assessing everyday technology use, along with a duration estimation task. In Experiment 2, participants completed the same questionnaire to assess their technology use and an interval production task. A MANOVA showed significant differences between individuals with high and low technology use, in both the estimation and production tasks. All participants overestimated in estimation tasks, and under-produced in production tasks. However, participants with higher technology use overestimated and under-produced to a greater degree. These findings suggest that the relationship between everyday use of technology and temporal experience warrants further study. The mechanisms underlying this relationship are currently being investigated by the researcher.

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Time perception and peripheral body signals

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Many theories of time perception postulate some form of pacer-counter-model: A pacemaker emits pulses that are accumulated by a counter during a to-be-estimated time interval. These counts are then compared to a reference count in memory. Even though there is a lot of experimental evidence supporting predictions that can be derived from this model, it is not clear which anatomic structure functions as a pacemaker and how. Here we test whether the heartbeat can function as a pacemaker for time perception. In a reproduction task participants where asked to reproduce a time interval several times. Reproduced time intervals where then tested for significant symmetries to heart rate, including analysis of calibration of heart rate and target time as well as determining the critical time point in the heart beat cycle for count accumulation.

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Temporal dysfunction in traumatic brain injury patients

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Introduction: Given the vulnerability of the frontal lobes to damage as a result of a Traumatic Brain Injury (TBI) and the common occurrence of executive dysfunction following TBI it seems reasonable to expect that time perception would be affected in TBI patients. To our knowledge only three studies have investigate time estimation abilities in TBI patients (Meyers & Levin, 1992; Perbal et al., 2003; Schmitter-Edgecombe & Rueda, 2008). All studies employed time reproduction tasks with duration ranged between 5 and 60 second. In the present study we investigate time perception in TBI patients employing a time discrimination task. Furthermore, since we used a discrimination task where stimuli are presented in temporal succession, we further investigate the presence of a Time-Order Error (TOE).

Participants: Twenty-seven severe-moderate traumatic brain injury patients took part at the study. The control group included 27 participants, matched for sex and education.

Time discrimination task: Two standard durations were employed: 500 and 1300 ms. The comparison stimulus was +/-25% respect to the standard. Participants were instructed to press two distinct keys if the second stimulus presented was longer or briefer compared to the standard. The stimuli used were smiley face, black and white coloured presented centrally in a grey background.

Results: TBI patients were less accurate compared to control. Different pattern of results were found in TBI patients and controls: when the standard duration was 500 ms TBI patients performed significantly worse than controls, when the second stimulus was longer than the standard, while with longer duration the opposite pattern of results was found. The ANOVA conducted on the number of 'long' responses yielded a significant main effect of group and duration. Patients showed a tendency to respond significantly more often 'long' in the 1300-ms than in the 500-ms condition.

Discussion: TBI patients are less accurate than control when engaged with durations briefer than few second. It could be possible that the deficit presented in TBI patients is mainly do to speed processing dysfunction instead of a purer temporal dysfunction. These data seems to be confirmed by the analysis of the TOE, in fact TBI patients seem to be more affected by the bias compared to control participants.

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Split-interval duration discrimination

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A variety of models have been proposed in an attempt to clarify temporal processing, some employing a specialized mechanism dedicated to interval timing whilst others suggest time perception is inherent in neural dynamics. A prominent model known as the pacemaker-accumulator internal clock (Creelman, 1962; Treisman, 1963; Church, 1984; Gibbon et al., 1997) has been likened to a stopwatch which can be stopped temporarily and restarted on demand. The current study aims to investigate this premise by measuring variable performance errors in a set of temporal discrimination tests. In addition to comparing two auditory intervals in a standard discrimination test, participants will be required to compare the sum of two intervals with a single standard interval. The predicted decline in task performance under a stopwatch model will be calculated in accordance with Weber's Law and compared to data generated by the participants. The results are expected to conform to a preceding study (Yarrow, unpublished manuscript) whereby the observed performance decline exceeded the stopwatch prediction providing support for alternative models of interval timing.

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EEG Time-Frequency Analysis of Temporal Memory

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Duration magnitude modulates positive slow wave event-related-potential (ERP) amplitude at frontal and central electrode sites during the S1-S2 interval in a temporal discrimination task (Ng et al., 2009). This finding suggests that longer durations require greater cognitive resources for working memory representation as compared to shorter durations. However, it is presently unknown whether the EEG frequency bands (e.g. alpha, beta, gamma) previously associated with non-temporal memory processes (e.g., Kaiser & Lutzenberger, 2005; Palva & Palva, 2007), are similarly modulated.

In another experiment with a similar setup, S1 and S2 were empty visual intervals separated by 2000 ms and participants indicated by key press whether S2 was the same or different from S1. Three S1 intervals (1500, 3000, & 4500 ms) were used. ERPs of correct trials during the S1-S2 delay period were generated using EEGLAB. Frequency decomposition of ERPs into commonly defined frequency bands was done using the ERPWAVELAB toolbox at each electrode site. Event-related spectral perturbations (ERSP) were also calculated at six ROIs (Left/Right x Frontal/Central/Parietal) across four time windows (0-500-1000-1500-2000ms), similar to the previous experiment. Preliminary inspection of the data from eleven participants showed that 1) ERP global field power (Skrandies, 1993) of longer S1s was larger than shorter S1s during the S1-S2 interval, and 2) ERSPs of longer S1s was more positive than shorter S1s at some frequency bands such as beta. These observations are in line with the hypothesized inhibitory processes of task-irrelevant information during memory maintenance (Schubotz & Friederici, 1997), including response preparation (cf. Pesonen et al., 2007). This need for inhibition may be greater when S1 is longer because of the higher degree of estimation uncertainty. This manifests as increased synchronization of scalp electrical signals. Moreover, the results can demonstrate the value of studying the properties of time perception/ estimation using general working memory paradigms and scalp EEG.

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Do pigeons perceive time relatively?

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The study investigated the effect of relative and absolute stimulus-response mappings on time discrimination in pigeons. In a matching-to-sample task, subjects learned to choose the right or the left comparison keys following a short and a long sample, respectively. In an ABA design, the sample durations equaled 1s and 4s (phases A) or 4s and 16s (phase B). Subjects were divided into two groups. In the Relative group the keys associated with the short and the long samples remained the same across phases. In the Absolute group the key associated with the 4-s sample remained the same across phases. We asked which group would learn faster and more accurately the discrimination during the last two phases. Results showed differences between the groups in the pattern, but not in the speed, of acquisition. The groups also did not differ on steady-state performance. Thus, a relative or absolute stimulus-response mapping does not seem critical for learning a temporal discrimination, a result that fails to corroborate the 'relational encoding' hypothesis of time perception.

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How Task Demands Influence Time Perception: A Computational Model

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The duration of incidents in dynamic human-machine systems represent crucial information for system analysis and the regulation of task-performance. With rising task demands people tend to be less reliable in time-estimations and cause errors in their interaction with a complex system.
To predict performance-errors due to difficulties in time-estimation a model is needed to explain the relationship of task demands and time-estimation. This model can then be applied in prospective stages of the design process of complex systems.
A model of prospective time-estimation was developed which explains the interplay of working memory demands on duration estimation. The model predicts the influences of task demands on time estimations by means of memory processes. The approach is integrated into a cognitive architecture ACT-R (Anderson, 2004) and tested with a user model of the counting task (Dutke, 2005). The duration of this task, which varies coordinative and sequential demands on working memory, had to be estimated. The comparison with experimental data shows that the model is able to simulate the influence of these demands on human time-estimation (Pape & Urbas, 2008).
The model was then tested in two experimental variations of the counting task. The aim was to test the time estimation-model in a realistic operator task including supervision and interaction with a complex system. In such a context, time critical behaviour is crucial for good operator performance.
The model predicts that sudden changes in specific task demands lead to under- or overestimates in time, depending on the direction of change. The empirical results go in line with the predictions of the model in addition to some other effects that are caused by the experimental variations such as repetitive reproductions (Rußwinkel, Urbas, & Thüring, 2011).
The results of the experiments and the model are discussed against the background of benefit of cognitive modelling.

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Event-related synchronization and interval timing

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The cortical processing of interval timing on the order of seconds was studied by electroencephalography. A general information processing (IP) model of time perception was tested with an event-related synchronization/ event-related desynchronization (ERS/ERD) analysis. The IP model assumes the existence of a clock, a memory and a decision stage. The purpose of the present study was to define how the modules of the IP model interact on a millisecond scale. In particular the aim was to define when the memory module would get activated. It is assumed that memory encoding and retrieval is reflected in ERS in the theta frequency band (Klimesch, 1999) Participants had to produce 2.5 s intervals by two key presses. They started uninformed about the target duration. Feedback was presented at the end of each trial, which enabled the participants to approximate the target duration. The analysis focused on the FCz electrode located above the supplementary motor area. Alpha and theta-band oscillations showed anticorrelated activity, which suggests good cognitive performance. The results indicate that memory processes are most preeminent during responses, i.e. the beginning and the end of each interval, and during feedback presentation.

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Auditory and visual temporal sensitivity: Evidence for a hierarchical structure of modality-specific and modality-independent levels of temporal information processing

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The present study investigated modality-specific differences in processing of temporal information in the subsecond range. For this purpose, participants performed auditory and visual versions of a rhythm perception and three different duration discrimination tasks to allow for a direct, systematic comparison across both sensory modalities. Our findings clearly indicate higher temporal sensitivity in the auditory than in the visual domain irrespective of type of timing task. To further evaluate whether there is evidence for a common modality-independent timing mechanism or for multiple modality-specific mechanisms, we used structural equation modeling (SEM) to test three different theoretical models. Neither a single modality-independent timing mechanism, nor two independent modality-specific timing mechanisms fitted the empirical data. Rather, the data is well described by a hierarchical model with modality-specific visual and auditory temporal processing at a first level and a modality-independent processing system at a second level of the hierarchy.

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Electrophysiological correlates of reference memory in Parkinson's disease

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Introduction: Neuropharmacological studies suggested the processing of time intervals in the milliseconds and second range is strictly related to the dopaminergic circuits. Evidences of the involvement of such circuits have been further provided by clinical studies on patients with Parkinson's diseases. Nevertheless, the presence of interval timing deficits Parkinson's disease is still a matter of debate. The present study aimed at investigating electrophysiological correlates of temporal discrimination process in a sample of patients with Parkinson's disease.
Methods: We tested a sample of eight patients with Parkinson, with mild to moderate severity (mean UPDRS = 5, SD= 3.78), which were first screened from a larger sample in order to have cognitive performances in the normal range (mean age = 62.3 years, SD = 6.5). All patients were on-medication. An age and education matched control group was compared (mean age = 63.9 years, SD =8.04). A time discrimination task was presented, which consisted of two successively presented pairs of visual stimuli; the first stimulus (standard interval) could last either 500 or 1500 ms, the second stimulus (comparison interval) could have duration 20 or 30%, shorter or longer than the standard one. Participants were asked to compare the duration of the two stimuli and to determine whether the comparison interval was shorter or longer than the standard interval. The two standard durations were presented in two separate sessions. The EEG was recorded during the execution of the task from 32 electrodes.
Results: The two groups did not differ in accuracy and reaction times. However, ERPs differences between the two groups were reported in the 1500-ms standard duration condition. The control group showed a negative slow wave (CNV) during the comparison interval in centro-frontal sites, which for intervals longer than the standard terminated before the end of the stimulus, after a duration equal to the memorized standard one. In the Parkinson's disease group, the CNV did not show the shift in coincidence with the end of a duration equal to the standard, but the potential kept rising sustained till the offset of the duration.
Conclusions: ERP results suggest that the on-line comparison between the two durations, reflected by the CNV trend, was impaired in patients with Parkinson's disease and support the presence of a core deficit of memory for time in such clinical population.

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How time flies between ears and eyes - Bimodal integration processes in time perception

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Research on time perception has mostly focused on single modalities, or on the difference in performance between modalities. On the other hand, studies investigating cross-modal integration of sensory signals have only dealt with spatial perception, or temporal order perception. In several psychophysical experiments, we investigated how perception of duration changed when filled intervals comprised a combined audiovisual stimulus, versus when these intervals were in the auditory or visual domain alone. With a Bayesian graphical model, we fitted a logistic psychometric function on staircase adaptive interval discrimination judgments, and as such estimated posterior just noticeable differences (JND's) of the different conditions. In five out of eight subjects the bimodal JND decreased towards a predicted 'optimal estimate' derived from the obtained unimodal JND's. This preliminary evidence of an optimal integration effect is discussed within the framework of dedicated models of temporal encoding in which the cerebellum plays an important role. In light of this, a follow-up EEG study is brought forward in which differences in bimodal time perception are expected to predict the degree of oscillatory synchronization between regions of the different modalities.

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Exploring possible modulations of time perception through video gaming and training of working memory and processing speed

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Time perception is an aspect of our every day lives that we usually take for granted. Several models of cognition however, have attempted to account for the way we perceive time and make temporal duration judgments. According to one such model, Attentional Gate Model (AGM), each person's time perception is dependent on processes such as attention, working memory and processing speed. (Bar-Haim, Kerem, Lamy, & Zakay, 2010; Zakay, Block, & Tsal, 1999).

In order to examine the effect that the aforementioned processes might have on time perception, participants were asked to perform a production as well as a reproduction dual task. Subjects had to allocate their attention between two types of information processing. They had to perform a temporal (time estimation) and a non-temporal (identification and naming of a Greek letter) task simultaneously. According to AGM, the need to divide our attention will differentially affect production and reproduction dual tasks. (Pouthas & Perbal, 2004) In the production task, divided allocation of attention, should lead to duration judgments, which are longer than the actual time intervals, while division of attention in reproduction dual tasks will cause underestimation of the actual durations. (Zakay et al., 1999; Pouthas & Perbal, 2004).

The participants in our study were randomly assigned in one of three experimental groups. Subjects were trained for thirty days either on an action video game (group 1) – which according to previous research increase processing speed (Dye, Green, & Bavelier, 2009) -- or on brain training software which aimed at improving working memory (group 2) or processing speed (group 3) accordingly. Subjects were asked to perform the dual tasks before and after the thirty day training period. Supposing that video gaming and training on appropriate mental activity software actually do increase processing speed and improve working memory, we expect that participant's performance in the dual tasks at post-test will be different than that on pre-test. Specifically we speculate that improvement of working memory will lead in a loss of fewer pulses during encoding phase and as a result to increased time reproductions. (Pouthas & Perbal, 2004) Accordingly, increase of processing speed, theoretically should lead to the accumulation of a greater number of pulses, and as result to shorter time productions. (Zakay et al., 1999).

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The alteration of time perception across life span

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An enormous literature exists about the mechanisms of prospective and retrospective time perception. Previous findings suggest that cognitive factors (besides biological and neural factors) play an important role in order to explain, whether we perceive the duration of a certain time span as short or long. An often reported common sense phenomenon is the alteration of time perception across the life span. Most people will agree that time seems to pass increasingly faster with increasing age (Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005). To answer the question why this might be the case, astonishingly little information is available about the underlying mechanisms of the described 'age phenomenon'. The existing findings in the field of cognitive science suggest that attention and memory processes might be promising candidates to explain the 'age effect' of time perception. One possible explanation could be that cognitive schemata develop over the life span on the basis of previous learning experiences. Once established, cognitive schemata will yield a faster processing of repeated experiences, and therefore, presumably cause a shorter perceived duration. Since with increasing age it is more likely that a cognitive schema of an experienced situation already exists, this could be an explanation for the impression that time passes faster with increasing age. My interest of research is to investigate the 'age phenomenon' of time perception in order to discover the underlying mechanisms. In doing so, it seems to be important to consider besides the cognitive factors also the alteration of biological and neurological processes over the life span. I will introduce the planned research project as well as the results of a first study on the effect of repeated stimulus exposures on time perception.

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Search for cardiac and respiratory influence on time perception and rhythm reproduction

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Main goal of the work is to research phase correlation between heart rate and time perception variables. Special experiment was set up, where time perception is assessed using free reproduction task in which participants had to encode and reproduce the duration of various time intervals. Phases of the cardiac cycles were calculated by recently developed technique. Correlation was quantified by means of synchronization index. Results showed that for some time intervals there is essential deviation from uniformly distribution that indicated an interrelation between last moment of the reproduction interval and heart rate phase, namely diastole phase of the cardiac cycle. Also model with time delay in reproduction phase was considered. The results demonstrate increasing of the synchronization index for certain time delay.