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

1st TIMELY Workshop on the "Multidisciplinary Aspects of Time Perception"
Athens, October 7-8, 2010

Information, Programme, & Abstract Book

Organizers: Argiro Vatakis, Georgios Papadelis

Location: The workshop is held in conjunction with the Hellenic ACOUSTICS 2010 conference and will take place at the old rectorial building of the National Technical Univ. of Athens (42, Patision str. or 28).

Participation/Admission: Free

Credits: This workshop is kindly co - supported by the School of Architecture at the National Technical University of Athens.

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

TIMELY Management Structure

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

WG3 - Coordinator	Dr. Armin Kohlrausch
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ACTION GROUP 4 - *Uncovering the neural correlates of TP*

WG4a - Coordinator	Dr. Christine Falter
WG4 - Co-coordinator	Dr. Virginie Van Wassenhove
WG4b - Coordinator	Dr. Valerie Doyere

DAY 1 – October 7th, 2010

9:30 – 10:00	Coffee, Registration, & Welcome
	Conceptual and Measurement Issues of Time and Time Perception **Chair: V. Arstila**
10:00 – 10:30	Is time identical to becoming? – E. Klein
10:30 – 11:00	A.N. Prior's Conceptual Analysis of Time – P. Øhrstrøm
11:00 – 11:30	Does the present have a fixed duration? – J. Kiverstein
11:30 – 12:00	*Coffee Break*
12:00 – 12:30	A Moment to Reflect upon Perceptual Synchrony – M. A. Elliott
12:30 – 13:00	Temporal sensitivity changes with extended training in a bisection task in a transgenic rat model – V. Doyère
	Time Perception: Language, Development, Attention **Chair: J. Navarra**
13:00 – 13:30	Does Language Experience affect Temporal Order Perception? – Y. Bao
13:30 – 15:00	*Lunch Break*
15:00 – 15:30	On the perception of visual durational features in speech – A. Esposito
15:30 – 16:00	How linguists can help to illuminate time perception – B. Lewandowska-Tomaszczyk
16:00 – 16:30	Time perception in children: Empirical studies in a developmental perspective – A. D. Eisler
16:30 – 17:00	*Coffee Break*
17:00 – 17:30	What Types of Attention Are related To Prospective Duration Judgments? – D. Zakay
17:30 – 18:00	Concurrent Tasks do not Directly Influence Time Estimation – H. van Rijn
	Closing of the 1st Day of the Workshop - Dinner

DAY 2 – October 8th, 2010

9:30 – 10:00	Coffee & Registration
	Applications of Time Perception and the Use of Complex Stimuli **Chair: H. van Rijn**
10:00 – 10:30	Time Perception as a Key Ingredient of Robotic Intelligence – M. Maniadakis
10:30 – 11:00	Audio-Visual Event Detection, Multimodal Saliency and Movie Summarization – P. Maragos
11:00 – 11:30	Social Timing Behaviour in Musical Context – L. van Noorden
11:30 – 12:00	*Coffee Break*

	Neural Correlates of Time Perception in Humans and Animals **Chair: C. Falter**
12:00 – 12:30	Relating natural time with mental time through tomographic analysis of brain activity extracted from MEG signals recorded while subjects listened to music – A. A. Ioannides
12:30 – 13:00	Space, time and action – G. M. Cicchini
13:00 – 13:30	Neural Timing Mechanisms for Tactile Events – A. Tomassini
13:30 – 15:00	*Lunch Break*
15:00 – 15:30	From neural desynchronies to perceptual unity and back – V. van Wassenhove
15:30 – 16:00	Temporal processing creates a theoretical background for neurorehabilitation - E. Szeląg
16:00 – 16:30	*Coffee Break*
16:30 – 17:00	Neural Features of Encoding, Maintenance, and Decision Processes in an Ordinality Task Requiring Temporal Comparisons – W. H. Meck
17:00 – 17:30	Associative and cognitive decision rules in models of interval timing – J. Jozefowiez
	Closing of the Workshop

Abstracts

DAY 1 – October 7th, 2010

Conceptual and Measurement Issues of Time and Time Perception
Chair: Valterri Arstila, Department of Philosophy, University of Turku, Finland

Is time identical to becoming?

Ettiene Klein
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One hundred and thirty years after the work of Ludwig Boltzmann on the interpretation of the irreversibility of physical phenomena, and one century after Einstein's formulation of Special Relativity, we are still not sure what we mean when we talk of "time" or "arrow of time". We shall try to show that one source of this difficulty is our tendency to confuse, at least verbally, time and becoming, i.e. the course of time and the arrow of time, two concepts that the formalisms of modern physics are careful to distinguish.

The course of time is represented by a time line that leads us to define time as the producer of duration. It is customary to place on this time line a small arrow that, ironically, must not be confused with the "arrow of time". This small arrow is only there to indicate that the course of time is oriented, has a well-defined direction, even if this direction is arbitrary.

The arrow of time, on the other hand, indicates the possibility for physical systems to experience, over the course of time, changes or transformations that prevent them from returning to their initial state forever. Contrary to what the expression "arrow of time" suggests, it is therefore not a property of time itself but a property of certain physical phenomena whose dynamic is irreversible. By its very definition, the arrow of time presupposes the existence of a well-established course of time within which - in addition - certain phenomena have their own temporal orientation.

We think that it is worth while to emphasize the difference between several issues traditionally subsumed under the label "the problem of the direction of time". If the expressions "course of time", "direction of time" and "arrow of time" were better defined, systematically distinguished from one another and always used in their strictest sense, the debate about time, irreversibility and becoming would become clearer.

A.N. Prior's conceptual analysis of time

Peter Øhrstrøm
Department of Communication and Psychology, Aalborg University, Denmark

Within the philosophy of time in the 20th century, A.N. Prior (1914-69) was one of the most important scholars. He laid the foundation for modern tense-logic and temporal logic in general. He also revived the medieval attempt at formulating a temporal logic for natural language. Prior held that logic should be related as closely as possible to intuitions embodied in everyday discourse. In the 1950s and 1960s he laid out the foundation of tense-logic and showed that this important discipline was intimately connected with modal logic. Prior also argued that temporal logic is fundamental for understanding and describing the world in which we live. He regarded tense and modal logic as particularly relevant to a number of important theological and existential

problems. Using his temporal logic Prior analysed the fundamental question of determinism versus freedom of choice.

In my presentation, I intend to give a brief introduction to Prior's conceptual analysis of time. One of the most significant issues in this regard is Prior's analysis of the concepts of dynamic and static time (corresponding to McTaggart's so-called A- and B-concepts). In fact the use the two kinds of concepts gives rise to two languages, two ways of speaking about the temporal aspects of the world. The A-language (corresponding to dynamic time) may be said to deal with time as seen from within. The crucial notions in this approach are past, present and future. When the B-language (corresponding to static time) is used the temporal aspects of reality are seen from the outside. Here the important notions are before, after, simultaneous with. The relations and mutual dependencies between these two frameworks or languages had been investigated early in the 20th century by McTaggart. In his works, Prior carried out an even deeper analysis of the relations between these two ways of describing the temporal aspects of reality. He argued that there four important answers to the question regarding the relation between the A- and the B-notions (corresponding to what he called the four grades of tense-logical involvement). Prior himself argued that the B-notions can in fact be derived from the A-notions. (This corresponds to the 3rd or the 4th grade.) In order to do so, Prior had to construct what is now called a hybrid logic.

In order to deal with the relations between the A- and the B-language Prior also made use of the idea of branching time. Using this idea Prior presented a view on time corresponding to an indeterministic understanding of reality. In my presentation, I intend to discuss the origin and function of Prior's notion of branching time. I'll also argue that some of the branching time models he worked with can be criticized for identifying 'plain future' with 'necessary future', which means that the resulting temporal framework does not match the understanding of time on which everyday language is based. If this view is accepted it turns out that we should prefer what Prior called the 3rd grade.

Does the present have a fixed duration?

Julian Kiverstein

Department of Philosophy, School of Philosophy, Psychology and Language Sciences, University of Edinburgh, UK

Our experiences stretch out over time to embrace events that take up short intervals of time. We hear melodies, see movement and change, feel enduring sensations, and in each of these experiences an event is presented to us that takes time to unfold. Our experiences nevertheless present us with what seems to be the event as a whole. Now consider that whatever we experience, we experience in the present. We can remember the past and form expectations about the future, but all of our experience is necessarily confined to the present. Given that we can experience events stretched out over time, it would seem to follow that the present we experience must likewise stretch out over an interval of time. The present that we experience must have duration.

What must experience be like if it is to take place in a present that has duration? Some philosophers have argued that experiences must last as long as the events we experience. Experiences on this view run concurrently with the events we are experiencing. Others have denied this and have argued that experiences have duration because they include a retentional element that reaches back into the past and an anticipatory element that reaches forward into the future. I'll focus on the former view in my paper, which following Barry Dainton I'll call the extensionalist view. Extensionalism, to be clear, denies that experiences are momentary states: I can be aware of events as a whole because the event falls within a single temporally extended experience.

To the extent that extensionalists view experiences as running concurrently with the events we experience they are committed to a view of subjective time (the amount of time an experience seems to take up) as mapping more or less exactly onto objective time (the amount of time an event takes up as measured by a clock). However we know that subjective and objective time can come apart in fairly radical ways. We all know that when we pay lots of attention to time, time seems to pass slowly, and the opposite effect is found when our attention is absorbed in the performance of an engrossing task. The extensionalist is committed to these cases being the exception rather than the norm. Thus Barry Dainton has written: "While the potential for discernible divergences between the duration of a stimulus and objective duration of the experience to which it gives rise can certainly be significant over the short term of, say 200msec or below – it is less so over longer intervals. (Otherwise such discrepancies would be more noticeable than they are in ordinary life)." ("The specious present: further isues" In Stanford Encyclopaedia of Philosophy, published 2010.) If these divergences between subjective and objective time are minimal and barely noticeable, we can treat the experienced present as having a fixed duration that maps neatly onto the timing of events in the world. What if these divergences are the norm even if often we don't ordinarily notice them? It would follow that we can't simply assume that subjective time behaves in the same way as objective time. This is the conclusion I will argue for in my talk.

A moment to reflect upon perceptual synchrony

Mark A. Elliott

School of Psychology, National University of Ireland, Galway, Republic of Ireland

How does neuronal activity bring about the interpretation of visual space in terms of objects or complex perceptual events? If they group, simple visual features can bring about the integration of spikes from neurons responding to different features to within a few milliseconds. Considered as a potential solution to the binding problem it is suggested that neuronal synchronization is the glue for binding together different features of the same object. This idea receives some support from correlated- and periodic-stimulus motion paradigms, both of which suggest that the segregation of a figure from ground is a direct result of the temporal correlation of visual signals. One could say that perception of a highly correlated visual structure permits space to be bound in time. However, on closer analysis the concept of perceptual synchrony is insufficient to explain the conditions under which events will be seen as simultaneous. Instead, the grouping effects ascribed to perceptual synchrony are better explained in terms of the intervals of time over which stimulus events integrate and seem to occur simultaneously. This point is supported by the equivalence of some of these measures with well established estimates of the perceptual moment. However, it is time in extension and not the instantaneous that may best describe how seemingly simultaneous features group. This means that studies of perceptual synchrony are insufficient to address the binding problem.

Temporal sensitivity changes with extended training in a bisection task in a transgenic rat model

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2-Dept of Psychology, Queens College, Flushing, NY, USA

The temporal bisection procedure has been used extensively to study temporal perception in animals. The procedure is a variant of the classical psychophysical method of constant stimuli. The procedure entails an initial conditional discrimination training phase in which one response is rewarded following a short duration stimulus, while another response is rewarded following a long duration stimulus. In a subsequent test phase, the short and long anchor stimuli are presented in addition to intermediate test durations. Using that procedure, we investigated temporal perception in a neurodegenerative transgenic rat model. After initial discrimination training in which animals learned to press one lever after a 2-s tone duration, and another lever after an 8-s tone duration for food reward, temporal perception was tested using the bisection procedure in which intermediate nonreinforced durations were presented in addition to the anchor durations. Bisection tests were repeated monthly in a longitudinal design from 4 to 8 months of age. The results showed that response latencies evolved from a monotonic step-function to an inverted U-shaped function with repeated testing, a precursor of nonresponding to intermediate nonreinforced durations. On the basis of runway findings, indicating greater sensitivity to reward magnitude reduction in transgenics than in wildtype controls, we infer that transgenics were more sensitive to nonreinforcement in the bisection test than were controls, accounting for the observed difference in behaviour in that procedure. We thus inferred that temporal sensitivity and incentive motivation combined to control the transformation of the bisection task from a two-choice task at the outset of testing to a three(or more)-choice task with repeated testing. Changes in the structure of the task and/or training repetition were accompanied by improvement in temporal sensitivity. In sum, the present data highlight the possible competing role of sensory and nonsensory factors in the temporal bisection task, such that nonsensory factors may compensate for deficits in temporal processing. Both factors should be taken into account when interpreting temporal performances under biological manipulations in the temporal bisection task when intermediate durations are discriminably different from anchors.

Time Perception: Language, Development, Attention

Chair: J. Navarra, Fundació Sant Joan de Déu, Hospital Sant Joan de Déu, Spain

Does language experience affect temporal order perception?

Bao Y.[1,3], Szelag E.[2,3,4], Szymaszek A.[2], Wang X.[1], Fang Y.[1], Pöppel E.[1,3]
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The ability to discriminate the temporal order of two successive auditory events has been suggested as a fundamental basis for language processing. However, whether language experience also affects temporal order perception remains unclear.

In the present study, we tested 18 Chinese and 18 Polish young adults with three temporal order tasks - one used two clicks, one used two near-frequency tones, and one used two far-frequency tones. The clicks were presented monaurally, while the tones were presented binaurally. Subjects

were asked to indicate the temporal order of the two auditory events. A minimum time interval between the two auditory events corresponding to 75% correctness was calculated as the temporal order threshold.

Compared with the similar higher temporal order thresholds in click task for both language groups, the two tone tasks showed a very interesting pattern of results. While Polish young adults were good at discriminating far-frequency tones with near-frequency tone performance similar to clicks, Chinese young people demonstrated significantly lower order thresholds in near-frequency tones with far-frequency tone performance similar to clicks. These results seem to suggest two different mechanisms for detecting the temporal order of clicks and tones. Besides a common mechanism for temporal information processing for clicks, the temporal order perception for pitch-related tones are possibly shaped by long-term exposure to native language environments.

To further test this language effect on temporal order perception, the same three temporal order tasks were again examined in a group of native Chinese students who learned the language of Russian, which is similar to Polish, and had passed a higher level Russian proficiency test. Consistent with a language impact, these Russian-learning Chinese showed significantly decreased order thresholds not only in near-frequency tones but also in far-frequency tones relative to clicks, although the decrease of order threshold in far-frequency tones was smaller than that in near-frequency tones.

These results seem to further suggest that language experience do have an impact on temporal order perception. Reasons underlying this language effect might be related to the unique distinctions between tonal language such as Chinese and non-tonal languages such as Polish and Russian. A holistic processing of temporal order perception is possibly shaped by each speech environment. A unique temporal window of optimal processing is created for each speech system which is adaptive to its own language environment, but non-adaptive to other speech systems.

On the perception of visual durational features in speech

Anna Esposito

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IIASS, Vietri sul mare (SA), Italy

This talk discuss about the perception of duration as distinctive cue in the recognition of speech sounds.

Duration plays a role in disambiguating speech either at segmental level, or in running speech, or at prosodic level. Experimental data, reported by many authors, showed that segmental duration is used as a distinctive cue for the recognition of speech segments as vowel and consonants. Phoneme recognition strongly depends either on the intrinsic duration of the speech segment, or the phoneme spectral change's duration, or the relative timing of two overlapping events.
Excerpts of fluent speech are not very well perceived by listeners below a given duration threshold, and "phonemic clauses", at a large extent, are signalled either by a speech pause, or the lengthening of the final word or syllable in the clause, or the pitch contour.

At the light of these considerations, the role of visual temporal cues in phoneme discrimination is investigated. The present work is a pilot study conducted on 10 native Italian speakers asked to compare and identify if there are differences in the facial movements when comparing pairs of video recordings where a Italian native speaker was producing minimal pairs of single and geminate Italian words. The participants identified differences between the two set of stimuli in

70% of the cases suggesting there is a visual perception of time variation in language. Consideration are made on on this visual perception of time.

How linguists can help to illuminate time perception

Barbara Lewandowska-Tomaszczyk
University of Lodz, Poland

The analysis of temporal expressions provides insights into language and culture-specific aspects of time perception and conceptualization. Despite the recent attempts to provide a theoretical framework for language independent normalization of temporal expressions (e.g., TimeML – Pustejovski et al. 2005), the full complexity of language structures used to describe time in general and time-grounded events (Lewandowska-Tomaszczyk, in press) remains beyond the reach of currently available natural language processing systems. Further corpus-driven research to be undertaken by the Lodz University TIMELY team is needed to fully describe the temporal anchoring of textual event mentions. On a practical level, a better understanding of the use of time expressions may not only lead to improvements in the performance of event extraction Natural Language Processing systems, but it can also be applicable in translation and inter-cultural communication studies (Deckert, forthcoming).

One particular line of research we would like to pursue is the analysis of temporal metaphors generally (e.g., TIME IS SPACE) and in selected Polish and English collocations (e.g. to waste time) in the framework of Cognitive Linguistics (Lakoff & Johnson, 1980) on the basis of large amounts of language data, i.e. applying Cognitive Corpus Linguistic methods (Lewanowska-Tomaszczyk & Dziwirek, 2009). The basic purpose is to identify the differences and similarities in the linguistic patterns used in both languages to denote temporal information. The extraction of collocates of adverbs of time with dedicated corpus search tools seems to be a natural starting point for such an analysis (Pęzik, 2010). In other words, statistical methods can be used to extract adverbs of time, such as quickly, slowly, which function as node words in collocations such as become quickly apparent or slowly shifting attitudes. A contrastive analysis of such collocations across two or more languages performed by the Lodz University team is likely to reveal the different cognitive mechanisms in the conceptualization of various classes of temporally-grounded events and shed some light on culture and language-specific time perception.

References

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Time perception in children: Empirical studies in a developmental perspective

Anna D. Eisler & Hannes Eisler
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While numerous studies have been conducted on time perception, only a few of these deal with children, and most of these used an approach that integrates information regarding time, speed and distance in the Piagetian tradition.

Piaget claimed that conceptual thinking develops independently of perception. He stated that children's gradual acquisition of temporal concepts is closely correlated with the development of their use of language. He explained that our awareness of time is a product of human evolution, and our ideas of time are neither innate nor automatically learned, but is an intellectual construction resulting from experience and action. Piaget also suggested that around the age of seven to eight years, children become capable of correctly classifying information on the succession and duration of events (Piaget, 1969).

Surprisingly, little subsequent research has been attempted to explore more directly time perception (subjective experience of time) in relation to physical (clock) time in children in a developmental perspective. The purpose of the present experiments was to compare time perception in a prospective paradigm (the experience of time-in-passing) in two groups of children aged 11-13 and 14-16 years with adults aged 19-45 years, using short standard durations and the psychophysical methods of reproduction (Experiment 1), and verbal estimation in subjective seconds (Experiment 2). The results show that reproductions did not differ between the three groups (Experiment 1), while in verbal estimation a developmental trend was found (Experiment 2). The younger group of children estimated the standard durations longer and less veridical than the adults. The estimates of the older group of children lay in between. The ability of children to reproduce standard durations like adults may be due to that the method of reproduction is more based on biological processes and less influenced by cognitive factors, as opposed to verbal estimation, which requires a wide variety of cognitive experiences. The findings also indicate that even the younger children at the age of 11-13 years understand the abstract concept of time, which is clearly evident from the fact that they are able to use conventional time units (seconds) in a consistent way (approximately linearly related to the standard durations), despite their tendency to estimate the standard durations longer than the adults. The reason for this is probably that, besides a certain lack of cognitive experiences, psychological (subjective, perceived) time passes slower for children than for adults, which is in line with Fitzpatrick´s statement (1980). The present findings contradict Fraisse who stated that the abstract quality of the time sense generally does not appear before an age of fifteen years (Fraisse, 1963).

What types of attention are related to prospective duration judgments?

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Prospective duration judgments (PDJ) are highly dependent on attentional processes. A model which provides an explanation for the attentional processes which underlie PDJ is the Attentional Gate Model (AGM). According to AGM, PDJ always compete on attentional resources with concurrent non-temporal tasks. Attention has to be divided between temporal and non-temporal tasks. When non-temporal tasks demand low level of attentional resources the amount of attentional resources that can be allocated for temporal processing is high and as a result PDJ's are longer, as compared with respective PDJ's when concurrent non-temporal tasks demand high level of attentional resources. The traditional perspective of attentional resources considered attentional mechanisms to be of one type. Recent developments in this domain suggest that there are four different types of attentional mechanisms: executive attention, selective attention, orienting of attention and sustained attention. In a series of studies, the attentional profile of participants as well as their level of performance on PDJ tasks was measured. The attentional profile was defined via specific tests and indicated the level of performance on each one of the four attentional mechanisms. The findings revealed that whereas executive, selective and orienting of attention were not linked to PDJ's performance, the sustained attention mechanism was significantly linked to PDJ's performance. This indicates that the sustained attentional mechanism is the one which can explain prospective timing processes. This finding shed new light on these processes and elaborates our understanding of temporal cognition.

Concurrent tasks do not directly influence time estimation

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2-University of Amsterdam, Netherlands

Most theories related to temporal cognition assume that attention is required to process temporal information: If a secondary, concurrent task requires attention, subjective time events occur less frequently, causing a "stretch" of subjective time. An alternative account (Taatgen, Van Rijn, & Anderson, Psychological Review, 2007), suggests that the effects of concurrent tasks on time estimation are at least partly caused by non-temporal demands to the cognitive system. As Taatgen et al. used a fairly complex task, question remains whether the explanation based on non-temporal demands also extends to simpler tasks. In two experiments, participants reproduced previously learned time periods of 4 seconds during which they performed a simple two-choice decision task, or a more complex lexical decision task at different SOAs. Although a cursory view of the data might seem to support an attentional modulation theory, more detailed analyses paint a different picture: As the estimations did not depend on the complexity or duration of the secondary task, these data provide additional support for the view that attention does not directly affect the accumulation of subjective temporal events.

DAY 2 – October 8th, 2010

Applications of Time Perception and the Use of Complex Stimuli
Chair: Hedderik van Rijn, University of Groningen, Netherlands

Time perception as a key ingredient of robotic intelligence

Michail Maniadakis, Panos Trahanias
Institute of Computer Science, FORTH, Greece

The sense of time is a fundamental capacity for humans and other animals. Contemporary research endeavours in intelligent artificial systems aim at equipping autonomous robots with human-like cognitive skills, in an attempt to promote robotic intelligence and make artificial agents more natural and more human-friendly. Surprisingly, despite the crucial role that time has in our daily activities, the capacity of robotic agents to experience the flow of time remains largely unexplored.

The inability of existing artificial systems to perceive time, constrains their understanding about the temporal characteristics of the dynamically changing world, rendering them unable to consider the linking and the temporal relationships of phenomena. Moreover, time processing plays a crucial role in the development of high level cognitive capacity based on the synthesis of primitive behavioural and cognitive skills (e.g. mind reading or prospective memory). The latter, in conjunction with the inability to reason about time, explains the difficulty of existing artificial agents to operate autonomously and intelligently in the real world.

Recently we have investigated autonomously self-organized artificial cognitive systems, exploring the role that time plays in shaping their behavioural and mental processes. Our study revealed that artificial agents tend to consider and exploit the temporal characteristics of the environment, developing time estimation mechanisms that facilitate the accomplishment of tasks. However, the rather simple time processing skills self-organized in our works can hardly compare to the natural time perception capacity, and they are clearly far below the full extent of human and animal temporal processing.

Future research efforts may capitalize on recent neuroscientific findings exploiting the principles of time processing in the brain in order to successfully proceed towards equipping artificial systems with time experiencing capacity. The issue of artificial time perception is a very complicated task that requires research efforts to be directed along different, yet interconnected topics. In particular, the underlying research needs to address the broad range of temporal experiences we have in our daily life. Directions for productive research work include among others: (i) duration processing, i.e. how we process the temporal length of phenomena and how we consider durations at different time scales, (ii) mental time travel, i.e. how we, at the present time, think about past and future events, (iii) ordering, i.e. how we perceive precedence and temporal causal relationships amongst events, (iv) specious present and simultaneity, i.e. how events that start and end at close but different moments, are experienced as occurring concurrently, (v) social time, i.e. how we consider the time of others, and how we share with them a common understanding on the temporal properties of the world.

Overall, due to the central role of time in human daily activities, the integration of temporal cognition in the perceptual, behavioural, emotional and communicative processes of artificial agents has the potential to significantly contribute in the seamless integration of robots into human societies.

Audio-visual event detection, multimodal saliency and movie summarization

Petros Maragos

National Technical University of Athens, School of Electrical & Computer Engineering, Greece

This talk presents a brief overview of ideas, methods and research results in multimodal attention-based event detection with emphasis on audio-visual fusion and application to movie video summarization. The underlying conceptual and computational framework includes multi-sensory integration, integration between low-level cues and high-level semantics, and tracking of the evolving dynamics along the time direction.

Social timing behaviour in musical context

Leon van Noorden & Marc Leman

Institute for Psycho-acoustics and Electronic Music, IPEM, Ghent University, Belgium

Music functions to a large extend in a social context. It is most of the time produced to be listened to by many people and in its production often more than one person is involved. In many circumstances listeners are not supposed to sit still but to move to the music in a more or less expressive and/or formal way.

Music develops in time. So, many temporal aspects of the sound produced and the movement of the agents involved can be studied. In a very large majority of musical pieces a regular temporal structure can be discerned, namely that of the pulse or beat. Especially music that is intended for informal dancing is characterised by a strong and regular pulse, so that the dancers can easily synchronise to the music and to each other. But also for the musicians themselves a regular pulse is an easy way to stay in time together. The less pronounced the beat and the more complex the rhythm the more difficult the performance is. Avant garde composers who prescribe different tempi for the performers will discover that the performers will choose aids like click tracks in order to produce what the composer asks.

In our institute we have studied the relation between temporal aspects of the music and movement of listeners and dancers to the music and between dancers in many different experiments. Some basic experiments such as walking in time to music with a large tempo range and synchronisation of children tapping on toy-drums to children's songs have led us to the conclusion that the musical pulse is grounded in an embodied resonance in our perception action system very close to 2 Hz. This is reflected in the histogram of musical tempi in a wide range of music programmes on the radio. The resonance, which is probably related to our locomotion system, makes it easier to synchronise.

Other experiments have shown that also in more complex musical situations listeners track the temporal structure of the music as they are invited to move along the music, such as in listening to chinese guqin music with large degrees of rubato and in the dance to complex music such as samba music in which it can be shown that people can move different parts of the body to different metrical layers in the music at the same time. We have also shown that the movements need not always be in strict synchronisation with the music, but can be produced in a kind of "counterpointal" way.

This knowledge about the temporal behaviour of people in the context of music has led us to develop equipment for people with motor problems and party games for children and adults.
The talk will give an illustrated overview of the different aspects of time perception and processing, as revealed in the empirical studies at IPEM.

Neural Correlates of Time Perception in Humans and Animals

Chair: Christine Falter, Department of Psychiatry, University of Oxford

Relating natural time with mental time through tomographic analysis of brain activity extracted from MEG signals recorded while subjects listened to music

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Imprints of external events on receptors in the periphery arrive in different brain areas, where parallel and asynchronous analysis takes place, at least in the first one hundred milliseconds or so. Yet, what the brain delivers to our consciousness half a second or so later is a unitary percept of a succession of events organized in what appears to be a rigid external spatial and temporal framework. How is this possible? We addressed this question using magnetoencephalography (MEG).

Much of early vision is devoted to the construction of the spatial framework. Objects are manipulated in terms of their intrinsic properties (mainly in the ventral part of the visual system) and placed in the 3D mental world generated (mainly by the dorsal part of the visual system).

Time in the visual system can be thought of as the movement of objects in a fixed a 3D background, with different timescales represented by the movement of different objects. The prototypical example being the movements of the hour, minute and second arms of a clock. Time evolution can be thought of as the unfolding of a never ending sequence of images. In our work we have studied timing of mental processes using presentation of single images. For example, we determined where in the brain and how soon the activity elicited by different facial expressions of emotion can be first distinguished. We showed that different brain areas are involved depending on where the stimulus appears in the visual field and that the task is usually completed well within 100 milliseconds.

Much of the early auditory system is concerned with separating distinct "sources" that are mixed in the same signal. For each auditory source its identity and other properties (including location) must be inferred from the time course of the signal it generates in each ear. The processing of auditory stimuli has been studied in some detail with MEG, mainly using simple tones, or simple sequences of tones. Unlike the visual system where a single image has meaning (e.g. it can represent an object) an instantaneous auditory signal is not meaningful. For example, in music: a single note is neither pleasant nor harmonious on its own; these attributes emerge in the context of the other notes; meaning is constructed in time. We have used authentic music as stimuli and produced tomographic (millisecond by millisecond) estimates of brain activity from the MEG signal recorded while subjects listened to the music. The time course and frequency analysis of regional brain activations identified areas responding to physical properties with fast (millisecond fidelity) or slow (music envelop). The correlation of features of the brain activations with features of the physical properties of the music showed which brain areas correlate to rhythmic properties of the music, including minute changes representing how the artist expressed the score. Surprisingly, one of the areas with activity best correlating to the acoustic features of the music was an area in the fusiform gyrus that is known to respond to complex visual stimuli, especially faces.

Space, time and action

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The idea that human timing is performed by a single centralized mechanism has recently been challenged by the proposal of simple distributed mechanisms. Over the last five years our lab has collected considerable evidence pointing to the existence of multiple "clocks" both for vision and other modalities. In particular we found that:

• Adaptation of a region of space to rapid visual motion decreases the perceived duration of visual events subsequently presented to that region of space [1].

• The spatial selectivity of the visual event adaptation is fixed in external, world-centred coordinates, (resistant to eye and head movements), pointing to a high-level centre for event timing, where motor and sensory information are integrated [2].

• Saccades compress strongly the perceived duration of event duration [3], and induce large distortions of simultaneity [3,4].

• Attention also has large effects on event duration [5].

• All these effects can be modelled assuming spatially specific clocks that decode the ongoing neural activity [4].

The main conclusion of all this research is that space and time are tightly linked, and both connected with action.

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Neural timing mechanisms for tactile events

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Adaptation studies [1,2] suggest that visual events are timed by multiple, spatially selective mechanisms anchored in real-world rather than retinal coordinates [2]. To test whether this is a general property of event timing we investigated timing mechanisms for touch, using a paradigm similar to that used in vision [2]. Subjects adapted to tactile motion by resting their right index finger on a corrugated grating etched on a wheel moving at 15cm/s (45Hz). After adaptation, subjects compared the duration of a test stimulus presented to the adapted finger to a probe (22Hz moving grating) presented to the index finger of the left, unadapted hand for 600ms. Given that motion adaptation reduces perceived speed and faster moving stimuli are perceived to last longer, we adjusted the speed of the test to compensate for the effect of adaptation. The apparent duration of the speed-matched test was reduced up to 40% (full adaptation). The effect was maintained when the test was presented to a different finger (right middle finger) in the same spatial location as the adaptor (spatiotopic adaptation) while it disappeared when the test was presented to the same finger but moved to a different spatial location (dermotopic adaptation).

We also tested if tactile timing mechanisms are influenced by changes in the current representation of the body and in particular if movement per se, not coupled with a change in spatial position, can alter the effect induced by adaptation. Two different conditions were examined: active movement, where the subject lifted his right arm at the end of adaptation and replaced it in the original position before the test stimulus started and passive movement, where the arm of the subject was lifted passively by the experimenter with a lever. We found that the effect of adaptation on apparent duration completely vanished when the body moved actively, while it remained unchanged when the body was moved passively. We suggest that the neural mechanisms for timing tactile events encode temporal information in a body-referenced framework and efferent motor commands may be of primary importance in constructing and updating a representation within which tactile events are timed.

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From neural desynchronies to perceptual unity and back

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For a given audiovisual source of information say, a speaker, it will take about 12 milliseconds for the transduced acoustic information to reach primary auditory cortex but about 50 milliseconds to observe neural responses in primary visual cortex. Similarly, when observing a red ball passing you by, colour is accessible about 80 milliseconds prior to direction (Zeki & Moutoussis, 1997a, b). With such considerations – neurally and perceptually based, respectively - why don't we experience the world as a stream of disjointed events? In this presentation, I will provide an overview of some empirical evidence drawn from human psychophysics, functional brain imaging and monkey neurophysiology suggesting that the brain intrinsically (parses and) reconstructs the temporal course of the sensory world. Specifically, how can we reconcile or account for perceptual time being in phase with veridical time? First, preliminary results will be introduced that provide new insights on the temporal boundaries of multisensory integration. Specifically, using a temporal visual search paradigm, the automaticity of information binding across the auditory and visual modalities is temporally bounded thereby providing evidence for the specificity in temporal parsing and potentially pre-attentional binding of audiovisual streams. Second, I will discuss the notion of integrative (vs encoding) windows of integration which have been reported in the context of complex or ecologically valid stimuli (such as speech). The range over which integration of audiovisual information integrates during a perceptual decision task (taken as implicit timing) and during a synchrony task (taken as explicit timing) are quite similar in healthy population. However, preliminary data suggests that in schizophrenic patients, the response profiles across the two tasks dissociate. These results raise a novel problem on the temporal constraints for multisensory integration and, importantly, on the perceptual access to temporal representations. Third, the computational implications of these data remain puzzling: for instance, within an integrative time window, temporal order disappears (by virtue of it being an integration process). If such is the case, the experienced continuity in perceptual streams owes to be reconstructed by specific computational means. Two notions in this context will be discussed, specifically those of prediction and postdiction in the construction of (present) subjective time.

Temporal processing creates a theoretical background for neurorehabilitation

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A number of neuropsychological evidence has documented that temporal processing provides one of the most fundamental principles underlying human cognition. The empirical support for such a statement comes from our studies focused on two different levels of temporal processing, namely on a high frequency processing (i.e. some tens of milliseconds range) and a low frequency processing (i.e. a few seconds time range). Such central role of timing in mental functioning led to the observation that many neurodevelopmental or neurodegenerative disorders are accompanied by deficient temporal processing. The recent studies conducted in our Laboratory constitute a major advance toward understanding how the brain encodes temporal information in these individuals. Moreover, in cross-cultural comparisons we indicated the similar pre-semantically defined temporal constraints of cognition on the level of some tens of milliseconds in both Polish and German samples.

These data allowed us to develop and verify empirically new neurorehabilitation methods based on specific training in temporal information processing. Three studies presented here address following questions: (1) can the temporal training reduce language deficits in aphasic patients? (2) can temporal training ameliorate cognitive function in healthy volunteers? (3) are there any neuroanatomical changes in brain activation after the training?

In study 1, aphasic patients participated in eight sessions of either specific temporal training (n=18), or control nontemporal training (n=7). Only temporal training yielded improvements in timing, moreover, a transfer of improvement from time domain to language domain (which remained untrained) was observed.

In study 2, Fast forWord training program was applied for ca. 8 weeks with four 1-hour sessions per week in elderly listeners (n=10, age: 65-75 years). After the training significant improvements in temporal-order judgment was accompanied by improvements in attentional resources (divided attention and vigilance). These cognitive improvements were not evidenced following the control nontemporal training.

In study 3, following Fast forWord training in young healthy students (n=15) we confirmed significant improvements in attention (divided attention and vigilance) as well as in new learning abilities. Furthermore, using fMRI we identified a dynamic neural network underlying temporal processing and found brain regions associated with improved timing following temporal training. After vs. before the training comparisons indicated brain activations more focused and shifted to typical 'timing structures', i.e. middle frontal gyrus (BA 10) of the right (difficult task) or left hemisphere (moderate task). These results clearly indicate that temporal training has neuroanatomical correlates and can be beneficial in improvement of cognitive function.

Such new therapy possibilities may be important with respect to development of new methods of not only language therapy but also broader cognitive therapies, addressing improvements of cognitive function in both young and elderly people. The cross-linguistic comparisons may indicate the potential benefits from such nonverbal temporal training worldwide, independently of the language (or cultural) background.

Neural features of encoding, maintenance, and decision processes in an ordinality task requiring temporal comparisons

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Apart from a handful of studies using primates, the ability of animals to make ordinal judgments is largely unknown. In order to investigate the ordinal competence of rodents, we trained rats on a novel temporal comparison task using auditory stimuli in which they were required to use ordinal information in order to classify the second of a pair of signal durations as being 'shorter' or 'longer' than the first. Such a task requires the timing/encoding of the first signal duration (standard), maintenance of that duration in short-term memory during a retention interval, followed by the timing/encoding of the second signal duration (comparison) and a decision in order to determine whether the comparison duration is 'shorter' or 'longer' than the standard duration. One can ensure that ordinal comparisons are being made by using a sufficiently broad range of standard durations whereby 'shorter' and 'longer' comparisons overlap with adjacent standards. In addition, the possibility that different timing/decision mechanisms are used for sub- and supra-second durations was investigated by using standards that ranged from 0.5s to 3.0s with 12 comparison durations spaced symmetrically around each standard in a proportional manner. The family of psychometric functions obtained from this procedure provides strong evidence that rats are able to make ordinal judgments across a wide range of signal durations, although their temporal sensitivity increased as a function of the standard duration rather than remaining relatively constant as typically shown in timing tasks where only a single duration needs to be timed. Following this baseline of ordinal judgment training rats were implanted with a micro-wire array with 8 electrodes in the dorsal striatum and 8 electrodes in the cortex. Single-unit activity as well as local field potentials were recorded and analyzed for each phase of temporal processing. In agreement with previous neuroimaging studies using fMRI in humans, the differential involvement of the supplementary motor cortex and striatum during temporal encoding, maintenance, and decision processes was exhibited.

Associative and cognitive decision rules in models of interval timing

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Models of interval timing in operant procedures all have three main components: (a) A short-term memory representation of the time elapsed since the onset of the time marker, (b) a long-term memory representation of the time of reinforcement, (c) A decision rule combining the short-term and long-term memory representation to generate behavior. This talk will deal with this latest component.

As far as the decision rule is concerned, models of timing can be divided in two categories. On one hand, we have models using a cognitive rule (ex: scalar expectancy theory, multiple-time-scale theory,...) where behavior is a function of a comparison between the short-term representation of time elapsed since the time-marker onset and the long-term representation of the time of reinforcement. On the other hand, we have models using an associative rules (ex: behavioral theory of timing, learning-to-time model, behavioral economic model,...) where behavior is a function of associations between time-dependent states and responding.

Two fundamental basic predictions of associative rule models concern the effect of reinforcement on timing and the context dependency of time perception. We will review data on those two issues, pointing out when they are consistent with associative models and when they are not, as well as suggesting ways in which cognitive models could be modified to account for them.

Finally, we will discuss the implications of the decision mechanisms for the representation of time by showing that, because of Weber's law, only some representation schemes are compatible with specific decision rules.

Our goal is to stimulate research on the effect on timing of context and reinforcement, which, we believe, will provide a fertile testing ground for theories of timing as well as a breeding ground for new ideas.