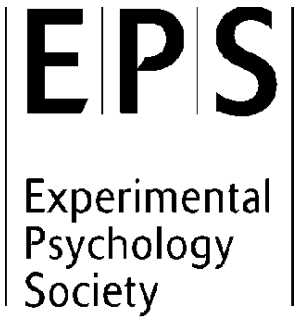
Modularity in Time Perception and Timed Behaviour

19th January 2017

Liverpool John Moores University



The workshop will be held at James Parsons Building, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF on the 19th of January.

Morning Session: Room 3.26 James Parsons Building

9:00 – 9:30 Welcome and coffee

9:30 – 10:00 SMA activity codes for the sequential integration of information in time but not space
Jennifer Coull, Aix-Marseille Universite & CNRS.

10:00 – 10:30 Distinct brain modules for the processing of? absolute and relative time?
Sundeep Teki, Dept. of Physiology, Anatomy and Genetics, University of Oxford.

10:30 – 11:00 Timing in clinical populations
Catherine Jones, School of Psychology, Cardiff University.

11:00 – 11:30 Coffee Break (room 3.23)

11:30 – 12:00 Prediction and anticipation driving eye movements in psychotic disorders
Rebekka Lencer, Andreas Sprenger, Peter Trillenberg, Annegret Meermeier, Svenja Gremmler, Markus Lappe, University of Luebeck, University of Muenster, Germany

12:00 – 12:30 Timing in music ensembles.
Alan Wing, Birmingham University

12:30 – 13:30 Lunch, Room 3.23 James Parsons Building. A selection of sandwiches and snacks.

Afternoon Session: Room 3.29 James Parsons

13:30 – 13:45 Do memory and executive function support a "general magnitude processor"?
Ruth Ogden, Liverpool John Moores University.

13:45 – 14:00 How do we control the speed of mental updating?
Alexis D.J. Makin, University of Liverpool.

14:00 – 14:15 How does the timing of transfer between the hemispheres change in older age? Interhemispheric connectivity during visuomotor transfer in the elderly
Brian Scally, Jean-Francois Delvenne, Melanie Rose Burke, University of Leeds.

14:15 – 14:30 Weighted integration suggests that visual and tactile signals provide independent estimates about duration.
Danny Ball[a], Derek Arnold[b] & Kielan Yarrow, [a]City University [b]University of Queensland.

14:30 – 14:45 Rate aftereffects fail to transfer cross-modally: Evidence towards distributed timing mechanisms
Aysha Motala & David Whitaker, School of Optometry and Vision Sciences, Cardiff University

14:45 – 15:15 Coffee break (room 3.24)

15:15 – 15:30 Dynamic Bayesian models for interval timing
Darren Rhodes, Anil K. Seth & Warrick Roseboom, University of Sussex.

15:30 – 15:45 Bayesian and sensory adaptation for relative timing
Warrick Roseboom, Darren Rhodes, & Anil Seth. University of Sussex

15:45 – 16:00 A review of pacemaker explanations of timing phenomena
Luke A. Jones, University of Manchester

16:00 – 16:15 Modality Differences in Timing: A New Take on an Old Issue
Emily A. Williams, Andrew J. Stewart and Luke A. Jones. University of Manchester

16:15 – 16:45 The modality paradox
John Wearden, Keele University

16:45 – 17:15 Close and discussion

17:30 – 19:00 Poster session and drinks reception
Location: Lower exhibition space James Parsons Building

The workshop will be held at James Parsons Building, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF on the 19th of January. The organisers are Ruth Ogden r.s.ogden@ljmu.ac.uk and Alexis Makin alexis.makin@liverpool.ac.uk.

By car

If you are travelling to the James Parsons Building by road and are using satellite navigation equipment you can enter the co-ordinates **53.412333,-2.981329** or the postcode **L3 3AF**. If you would like to reserve a car parking space please email Ruth Ogden r.s.ogden@ljmu.ac.uk

By rail

The James Parsons Building is ten-minute's walk from the nearest mainline station at Lime Street. Take the main exit and turn right onto Lime Street. Turn left at the Walker Art Gallery and continue towards Byrom Street. Turn right and cross the fly-over, then continue along Byrom Street until you reach the City Campus.

Coach

The National Express Coach Station is located at Liverpool One Bus Station, Canning Place, Liverpool L1 8LB, in the heart of Liverpool's city centre. From the coach station, follow signs for Lime Street Railway Station, then follow directions to the University from the station, as described above.

Accommodation

Affordable, quality hotels in the city centre include:
Hard Days Night Hotel: A Beatles themed hotel in central Liverpool. Rooms start from £80.00 per night. http://www.harddaysnighthotel.com/
The Liner Hotel: A nautically themed hotel in Central Liverpool. http://www.theliner.co.uk/

Grindley Grant

Postgraduate and post-doctoral students may be entitled to apply for a Grindley Grant from the EPS to fund travel and accommodation expenses.

Details of the grant and how to apply can be found here:

http://www.eps.ac.uk/index.php/grindley-grants-for-conference-attendance

Abstracts - Oral Presentations

SMA activity codes for the sequential integration of information in time but not space

Jennifer Coull, Aix-Marseille Universite & CNRS.

Functional neuroimaging studies of timing frequently identify the same corticostriatal network for the perception of duration. Yet different components of this anatomical network may serve distinct functional purposes: basal ganglia for initial encoding of duration, frontal and temporal cortices for comparison and decision processes, Supplementary Motor Area (SMA) for the sequential integration of temporal information. Indeed, activity in SMA increases as a function of both objective (physical) stimulus duration and subjective (perceived) duration. Moreover, these effects are specific to the temporal domain. We found that SMA activity increased as a function of the duration of a visual trajectory but not as a function of its distance, and even more so if participants were actively engaged in timing. By contrast, activity in visual cortex increased with stimulus duration whether participants were actively timing or not, suggesting the straightforward elapse of time itself is represented in sensory-specific processing regions.

Distinct brain modules for the processing absolute and relative time?

Sundeep Teki, Dept. of Physiology, Anatomy and Genetics, University of Oxford.

Time is a fundamental dimension of natural sensory signals like sound and music, as well as natural motor output like speech and walking. Time intervals in such natural sequences vary in time scale, ranging from a few hundred milliseconds to several seconds, as well as in temporal regularity, from being periodic and regular to being random and irregular (Allman et al., 2014). Recent evidence from behavioural and neuroimaging studies suggests that time intervals are perceived differentially depending on the temporal context of the sequences. Patients with cerebellar damage show deficits in timing intervals in regular sequences but not in discrimination of single time intervals (Grube et al., 2010) whilst Parkinson's patients with an impaired basal ganglia system show deficits in discrimination of rhythmic sound sequences (Grahn and Brett, 2009). To assess and resolve the relative contributions of the cerebellar and basal ganglia systems to absolute and relative time perception respectively, I designed a novel stimulus paradigm in which participants were required to discriminate the duration of two successive intervals that were preceded by induction sequences that were either regular (and isochronous) or irregular (and jittered). Analysis of the BOLD responses measured using functional MRI revealed distinct clusters for perception of absolute and relative time localized to the olivocerebellar network and the striato-thalamo-cortical network respectively (Teki et al., 2011). In more recent work, I examined the distinction between working memory for time intervals in regular and irregular sequences. Behaviourally, participants are better at remembering and reproducing the duration of a single interval (at both sub- and supra-second ranges) in regular vs. irregular sequences (Teki et al., 2014). Brain imaging data based on the same paradigm also revealed modulation of BOLD responses in the cerebellum and the basal ganglia as a function of the temporal context of the sequences (Teki et al., 2016). In conclusion, the temporal context in which a time interval is presented is behaviourally relevant and modulates the brain responses of the underlying subcortical networks based in the cerebellum and the basal ganglia (Teki et al., 2012).

References

Grube M, Cooper FE, Chinnery PF, Griffiths TD (2010) Dissociation of duration-based and beat-based auditory timing in cerebellar degeneration. Proc Natl Acad Sci USA 107:11597–11601.
Grahn JA, Brett M (2009) Impairment of beat-based rhythm discrimination in Parkinson's disease. Cortex 45:54–61.
Teki S, Grube M, Kumar S, Griffiths TD (2011) Distinct neural substrates of duration-based and beat-based auditory timing. J Neurosci 31:3805–3812.
Teki S, Grube M, Griffiths TD (2012) A unified model of time perception accounts for duration based and beat-based timing mechanisms. Front Integr Neurosci 5:90.
Allman MJ, Teki S, Griffiths TD, Meck WH (2014) Properties of the internal clock: first- and second-order principles of subjective time. Annu Rev Psychol 65:743–771.
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Teki S, Griffiths TD (2016) Brain bases of working memory for time intervals in rhythmic sequences. Front Neurosci 10:239.

Timing in clinical populations

Catherine Jones, Cardiff University.

Temporal distortions and difficulties are common to many clinical conditions, including neurological (Parkinson's disease), psychiatric (schizophrenia, depression) and developmental (autism spectrum disorder, attention deficit hyperactivity disorder) disorders. However, the nature and severity of these effects, along with the consistency of the findings, varies. A large body of work has investigated interval timing in clinical populations, which has furthered understanding of milliseconds- and seconds-range motor and perceptual timing mechanisms. Parkinson's disease, which results from degeneration of the basal ganglia, has been a particular focus of research, reflecting compelling pharmacological and animal work linking the basal ganglia to temporal processing. This talk will explore what clinical conditions, particularly Parkinson's disease, can tell us about interval timing.

Prediction and anticipation driving eye movements in psychotic disorders

Rebekka Lencer,[1, 3] Andreas Sprenger,[2] Peter Trillenberg[2,] Annegret Meermeier[4], Svenja Gremmler[4], Markus Lappe[4] [1] Department of Psychiatry and Psychotherapy & [2] Department of Neurology, University of Luebeck, [3] Department of Psychiatry and Psychotherapy & [4] Institute of Psychology, University of Muenster, Germany

The guidance of eye movements not only depends on the processing of visual sensory information but is considerably driven by prediction and anticipation of upcoming events. Continuous evaluation of these predictions and their prediction errors is used to optimize performance. To what extent the interaction of sensorimotor processing and higher order anticipatory control is disturbed in psychotic disorders is not well understood. While earlier studies have suggested an impairment of anticipatory and predictive input in patients, more recent studies suggest that predictive mechanisms may be even used by patients to overcome feed-forward sensory transformation deficits. We here discuss results from more detailed studies on different aspects of prediction during both smooth pursuit and saccadic eye movements. Our findings suggest that during pursuit patients with psychosis may rely on prediction based on short-term velocity storage to continue ongoing movements to a higher

extent than healthy controls. Other findings imply that despite sufficient capability to adapt motor behaviour to changes in prediction error, a certain instability in cerebellar saccadic control systems results in slowed adaptation speed. Together, this implies that under certain circumstances distinct predictive mechanisms are crucial for patients with psychosis for action planning and for optimizing oculomotor performance.

Timing in music ensembles.
Alan Wing, Birmingham University

My talk will be about modelling single and multi-person event-based synchronisation. I will follow a recently published review (Elliot, Chua and Wing, 2016; http://www.sciencedirect.com/science/article/pii/S2352154616300225) in first describing timing variability in synchronising finger tapping with metronomes (both fixed and time varying). I will then focus on multiperson synchronisation in music performance with examples from top class professional chamber music groups.

Do memory and executive function support a "general magnitude processor"?
Ruth Ogden, Liverpool John Moores University.

Developmental, behavioural and neurological similarities in the processing of different magnitudes (time, number, space) support the existence of a common magnitude processing system (e.g. ATOM; Bueti & Walsh, 2009; Walsh, 2003). However, it is unclear whether the processing of different domains of magnitude all require the same memory and executive functions. We previously have demonstrated that duration is more vulnerable to decay and interference in reference memory than other forms of magnitude (Ogden et al 2010), suggesting that memory function differs for different domains of magnitude. Furthermore, our assessment of how magnitude bisection performance (duration, number, length) is related to STM and executive function capacity suggests differential recruitment of wider cognitive resources during different forms of magnitude processing (Ogden et al., in press). Although these findings do not counter the idea of a universal magnitude processor, they highlight the need to fully integrate duration (and other magnitude) processing within a framework of wider cognitive processing.

How do we control the speed of mental updating?
Alexis D.J. Makin, University of Liverpool.

Sensory maps maintain a representation of the organism's immediate environment. Representations are updated automatically by input from the sense organs, for example, when we notice an object move or when someone starts speaking. However, we can also update representations top-down, in the absence of incoming sensory signals. This non-standard form of updating is closely linked to mental imagery (Shepard & Metzler, 1971). In many *motion extrapolation experiments*, we have demonstrated that humans can flexibly control the speed of such internal dynamic simulations (Makin & Bertamini, 2014; Makin & Chauhan, 2014). This leads to an obvious question: Is there a central *rate controller* or pacemaker module in the brain, that can be functionally coupled to sensory maps and drive updating? The putative rate controller has the same function as the *velocity store* described in Makin and Poliakoff (2011) but with a broader function than previously envisaged. Alternatively, each sensory map may be

endowed with a primitive intelligence, and tune into temporal regularity in the input stream. These local predictive mechanisms may be sufficient for prolonged mental simulation (Khoei, Masson, & Perrinet, 2013). Preliminary evidence supports the common rate control theory, although local predictive mechanisms may cover very short gaps in the input stream (<200 ms.). The putative rate controller could be conceptually reduced to the *pacemaker* module of the internal clock (Wearden, 2013), and could be a function of the core timing system in the dorsal striatum (Coull, Cheng, & Meck, 2011).

References

Coull, J. T., Cheng, R. K., & Meck, W. H. (2011). Neuroanatomical and Neurochemical Substrates of Timing. *Neuropsychopharmacology*, *36*(1), 3–25

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How does the timing of transfer between the hemispheres change in older age? Interhemispheric connectivity during visuomotor transfer in the elderly

Brian Scally, Jean-Francois Delvenne, Melanie Rose Burke, University of Leeds.

In the classic Poffenberger paradigm (1912) manual responses to lateralised stimuli are supposedly delayed when the stimulated visual field and the response hand are governed by opposing brain hemispheres. This is due to the requirements of interhemispheric transfer across the corpus callosum. There is little consensus on how mean reaction time (RT) and RT variability in the transcallosal and extracallosal response pathways are affected by healthy ageing, when interhemispheric white matter connections degrade naturally with age. We propose that traditional methods of measuring interhemispheric transfer using the Poffenberger paradigm and P1/N1 visual evoked potentials are associated with methodological shortcomings that have led to unreliable measurements of transfer, especially in the context of healthy ageing. Instead, we propose that interhemispheric EEG connectivity during transfer may reveal more about how transfer is affected by ageing. In this study we measured interhemispheric connectivity using EEG in young adults and healthy older adults while they performed the Poffenberger task. Task-induced connectivity was evident in the theta band (5-8 Hz) from 100-300ms, consistent with the P1/N1 time window. Theta connectivity was significantly stronger in older adults than in younger adults. Interhemispheric connectivity in the theta band had a significant negative relationship with transcallosal RT variability for older adults, but not for younger adults. The results suggest that for older adults, interhemispheric connectivity in theta may be indicative of white matter integrity in the corpus callosum, and that

higher connectivity allows older adults to match the performance of younger adults in terms of response time variability.

Weighted integration suggests that visual and tactile signals provide independent estimates about duration.

Danny Ball[a], Derek Arnold[b] & Kielan Yarrow[a]. Dept. of Psychology, City University London.School of Psychology, University of Queensland.

Humans might possess either a single (amodal) internal clock, or multiple clocks for different sensory modalities. Sensitivity could be improved by the provision of multiple signals. Such improvements can be predicted quantitatively, assuming estimates are combined by summation, a process described as optimal when summation is weighted in accordance with the variance associated with each of the initially independent estimates. We assessed this possibility for visual and tactile information regarding temporal intervals. In Experiment 1, 12 musicians and 12 non-musicians judged durations of 300 and 600 ms, compared to test values spanning these standards. Bimodal precision increased relative to unimodal conditions, but not by the extent predicted by optimally weighted summation. In Experiment 2, six musicians and six psychophysical observers each judged six standards, ranging from 100 ms to 600 ms, with conflicting cues providing a measure of the weight assigned to each sensory modality. A weighted integration model fitted these data best, with musicians more likely to select near-optimal weights than non-musicians. Overall, data were consistent with the existence of separate visual and tactile clock components at either the counter/integrator or memory stages. Independent estimates are passed to a decisional process, but not always combined in a statistically optimal fashion.

Rate aftereffects fail to transfer cross-modally: Evidence towards distributed timing mechanisms

Aysha Motala & David Whitaker, School of Optometry and Vision Sciences, Cardiff University, Cardiff, U.K.*

Time perception is important for a number of different tasks, some of which include understanding speech and appreciating music. However, it remains to be elucidated whether sensory time perception occurs due to a central timing component overlooking each sense or rather, that distributed mechanisms exist each specifically dedicated to each sense, and operating in a largely independent manner. To this end, a range of unimodal and cross-modal rate adaptation experiments were conducted, in which adapting to a fast rate makes a moderate rate feel slow, and adapting to a slow rate, makes the same moderate rate feel fast. Rate perception was quantified by a method of temporal reproduction across the visual, auditory and tactile senses on two experienced observers. Repulsive rate aftereffects were observed across all unimodal conditions however, no such effects were observed for any cross-modal pairings. We use the current findings to suggest that sensory timing abilities are open to change, but crucially, that this change is modality-specific and finally, that our data supports the distributed timing hypothesis.

Dynamic Bayesian models for interval timing

Darren Rhodes, Anil K. Seth & Warrick Roseboom, Sackler Centre for Consciousness Science, School of Engineering and Informatics, University of Sussex

Human perception appears to adhere to principles of Bayesian inference. Current sensory estimates (likelihood functions) are combined with expectations (priors) to produce a posterior distribution from which a perceptual estimate is taken. In time perception, the most prominent example of the influence of perceptual priors is that manually reproduced durations are biased towards the mean of previously experienced durations. However, the question remains as to how perceptual priors for time are acquired and maintained. To investigate this issue, we tested whether human subjects could concurrently maintain multiple priors for duration. We presented subjects with sequences of four visual flashed or auditory tones. The first three stimuli were separated by an isochronous interval, with the last stimulus jittered around this interval. Subjects reported if the final stimulus was early or late relative to expectation. In a trial block, intervals between successive auditory tones were, on average, shorter than for visual stimuli, or vice versa. We analysed the proportion of 'late' responses for each experimental condition by fitting a psychometric surface to our data, rather than independent cumulative Gaussians. We found that subjects can acquire and maintain two concurrent prior distributions, one for each sensory modality. We modelled the build-up of these priors using an iterative Bayesian inference model - a Kalman filter - that updates the prior probability distributions for each contingency with every single exposed interval. Together, our data provides evidence that perceptual priors can be modality general or context specific, and that these results can be described by simple updating processes.

Bayesian and sensory adaptation for relative timing

Warrick Roseboom, Darren Rhodes, & Anil Seth, *Sackler Centre for Consciousness Science, School of Engineering and Informatics, University of Sussex, Brighton, UK.*

Recent sensory experience can affect subsequent experience. For temporal perception, recent experience may produce positive or negative aftereffects, consistent with Bayesian or classical sensory adaptation descriptions, depending on presented signal type and exposure distribution. In the context of multisensory relative timing, there has recently been great controversy regarding the influence of recent exposure. While it has been well established that repeated exposure to, for example, audio events leading visual by ~200 ms, causes smaller audio-leading-visual offsets to be reported as synchronous more often - consistent with classic negative sensory aftereffects - other recent results indicate that a *single* exposure is sufficient to produce similar effects. This finding has been interpreted as *rapid* adaptation of audiovisual timing, equivalent to that known to occur following prolonged exposure. Consistent negative aftereffects produced by prolonged exposure have been demonstrated in all relative timing tasks. Consequently, if a single exposure alters audiovisual timing consistently with sensory adaptation, negative aftereffects should also be demonstrable across any task. We examined the influence of a given audiovisual relative timing presentation on judgements of subsequent presentations – serial dependence of relative timing – for standard relative timing tasks: simultaneity judgements (SJ), temporal order judgements (TOJ), and magnitude estimation (ME). While serial dependence for SJ appears consistent with previous results producing negative aftereffects, TOJ and ME produced *positive* aftereffects. To reconcile these conflicting results, we propose that the serial dependence reported for SJ results from a *positive* aftereffect

of the simultaneity judgement criteria, rather than a negative aftereffect of time as for sensory adaptation. This interpretation is consistent with simple Bayesian descriptions typically invoked for serial dependence, and provides two interesting conclusions: serial dependence for relative timing is not sensory adaptation; and purely positive aftereffects can *appear* as negative – a worrying prospect for many studies that claim altered sensory representation based only on behavioural negative aftereffects (e.g. face aftereffects).

A review of pacemaker explanations of timing phenomena

Luke A. Jones, University of Manchester

Due to the lack of a sense organ for time, explanations of timing phenomena are necessarily forced to speculate on hidden internal processes. One of these processes has been both extremely powerful (but also controversial), is that of an internal pacemaker-accumulator clock. On the one hand the assumption of the existence of an internal clock is consistent with a wide range of characteristics of human timing; e.g. linear timing, the ease of ordinality judgements, the precision of difference thresholds, as well as the ubiquity of everyday prospective timing (see Wearden & Jones, 2007). On the other hand it can be argued that some pacemaker explanations of timing phenomena are more problematic, such as explaining modality differences (e.g. Wearden, Todd & Jones, 2006), the filled-duration illusion (e.g. Wearden et al., 2007), and the affect of repetitive stimulation (click-trains and flickers, e.g. Penton-Voak et al., 1996). In this talk I will discuss evidence on both sides, the historical context of how we reached this point, and what empirical work we are doing to shed light on this issue.

Penton-Voak, I. S., Edwards, H., Percival, A., & Wearden, J. H. (1996). Speeding up an internal clock in humans? Effects of click trains on subjective duration. *Journal of Experimental Psychology: Animal Behavior Processes*, *22*(3), 307.

Wearden, J. H., and Luke A. Jones. "Is the growth of subjective time in humans a linear or nonlinear function of real time?." *The Quarterly Journal of Experimental Psychology* 60.9 (2007): 1289-1302.

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Wearden, J. H., Norton, R., Martin, S., & Montford-Bebb, O. (2007). Internal clock processes and the filled-duration illusion. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(3), 716.

Modality Differences in Timing: A New Take on an Old Issue

Emily A. Williams, Andrew J. Stewart and Luke A. Jones, University of Manchester.

A classic effect in the timing field is that “sounds are judged longer than lights” (Goldstone et al., 1959) and more recently that vibrations are judged somewhere between the two (Jones et al., 2009). This modality pattern is commonly interpreted within Scalar Expectancy Theory as the work of a central pacemaker which runs faster for sounds, then vibrations, and slowest for lights. We investigated whether verbal estimates and temporal difference thresholds are negatively correlated within each modality, but they were no found to do so. This suggests that a faster pacemaker is not necessarily a more accurate pacemaker. A second study investigated whether these modality differences could be explained by participants’ sensory biases. The

same participants completed cross-modal temporal order judgements (TOJ) and sensory bias was measured by their point of subjective simultaneity (PSS). No correlations were found between the differences in verbal estimation slopes and their respective sensory biases. This suggests that the modality differences are not due to sensory biases. Finally, a factor analysis explored whether measures of estimations, thresholds, PSS and just-noticeable differences (from the TOJ task) would cluster according to modality or measure. Five factors were found to account for 65% of the variance in the original variables, four of which were mainly dominated by each aforementioned measure. This suggests that, rather than a separate factor arising for each modality, factors were mainly separated by task. In other words, performance is more similar within each task than it is within each modality.

Goldstone, S., Boardman, W. K., & Lhamon, W. T. (1959). Intersensory comparisons of temporal judgments. *Journal of Experimental Psychology*, *57*, 243-248.

Jones, L. A., Poliakoff, E., & Wells, J. (2009). Good vibrations: Human interval timing in the vibrotactile modality. *The Quarterly Journal of Experimental Psychology*, *62*, 2171-2186.

The modality paradox

John Wearden, Keele University

It has been known since the 19th. Century that when stimuli of the same real duration are presented in different modalities (auditory, visual, tactile, filled and unfilled) aspects of their perceived duration are often different. The modality paradox, to paraphrase Filippopooulos et al. (2013), is as follows: If stimuli in different modalities are timed by different timing systems, why is behaviour often so similar? If they are timed by the same system, why are there any differences at all? This paper reviews the many similarities: similar forms of behaviour in tasks like temporal generalization, bisection, and verbal estimation, similar effects of repetitive stimulation, apparently similar properties in short-term memory, and interference in reference memory between stimuli of different types. But there are also differences: stimuli in some modalities seem consistently judged as longer or shorter than in others, and differences in timing variability may also occur, although this is less well-established. How can these similarities and differences be reconciled? Some potential approaches will be discussed including variable rates of temporal accumulation, and the possibility of a hierarchical timing system with modality-specific and modality-independent elements.

Filippopoulos, P.C., Hallworth, P., Lee, S., & Wearden, J.H. (2013). Interference between auditory and visual duration judgements suggests a common code for time. *Psychological Research, 77,* 708-715.

Abstracts - Poster Session

Time Perception in Autism Spectrum Conditions

Martin Casassus, University of Manchester

Time perception plays an important role in the organisation of reality and human social behaviour. A condition that shows impairments in both social interaction and time perception is Autism Spectrum Condition (ASC). Relatives and professionals frequently use (or completely avoid) time concepts when preparing ASC people for an oncoming change of activity, for instance 'we leave in 5 minutes', which involves a temporal understanding of a given duration (prospective time). We have recently completed a review of the literature on timing in autism. Different studies have shown differences between ASC and neurotypical populations (e.g. Allman et al. 2011), however, time perception studies in autism are limited by the paucity of published studies, lack of neurophysiological data, different characteristics of the groups studied (by age or number) and the diversity of methodologies employed. This scenario makes it almost impossible to compare results between studies or gain an accurate and unified description of time perception processes in autism. As consequence, we currently do not know; which processes involved in time perception are affected in ASC, how profound are the differences compared with neurotypical population, or what are the direct consequences in the different difficulties that ASC people present. This poster will present the current state in time perception research in autism and will propose a scheme of work that allows us to identify which aspects of time perception (in terms of perception of durations) are impaired and how those differences may be related with other difficulties in ASC.

Allman, M., DeLeon, I.G & Wearden, J.H. (2011). Psychophysical assessment of timing in individuals with autism. *American Journal on Intellectual and Developmental Disabilities, 116*, 165-178.

Response-irrelevant number, duration and extent information triggers the SQARC effect: Evidence from an implicit paradigm

Thomas Gallagher-Mitchell [1], Fiona Simmons [2], Ruth Ogden [21] Liverpool Hope University, UK, [2] Liverpool John Moores University, UK

A Theory of Magnitude (ATOM; Bueti & Walsh, 2009; Walsh, 2003) proposes that different domains of magnitude (e.g. time, space, numerosity) share a common neural processing system located in the parietal cortex. The argument that a common neural system is employed to process different domains of magnitudes is further supported by evidence that irrelevant information from one magnitude domain can disrupt judgements in another. The influence of task irrelevant magnitude on spatial processing (Fias, Lauwereyns & Lammertyn, 2001; Mitchell, Bull & Cleland, 2012) has been demonstrated using a neural-overlap paradigm demonstrating an interference effect of spatial-numerical magnitude on decisions about stimulus colour and orientation. The current paper extends this paradigm into the domain of time perception (in this case duration) and its influence on task-related orientation decisions. Forty participants completed stimulus response tasks to orientation of triangle stimuli under three different magnitude conditions; numerosity, size and duration. All magnitude information was implicit to task demands and no active decision was made to these task features. Across conditions the neural-overlap effect was assessed by presence of a significant negative beta weight regression

(SQARC effect) between implicit magnitude and response speed to stimulus orientation. Results indicated significant SQARC regression present in each task condition aligning with Walsh's proposed shared-network of magnitude processing. Implications for the ATOM model are discussed, as are ideas for cross-talk between magnitude domains.

Do you feel time passing? The role of interoception in arousal and time perception

Ben Fenner[1], Nicholas Cooper[1], Gethin Hughes[1] and Vincenzo Romei[1] [1]*Centre for Brain Science, Department of Psychology, University of Essex*

A wealth of research has shown that changes in physiological arousal influence time perception. At the same time, recent research has suggested that interoception – perception of changes in one's bodily state – influences the degree to which particular stimuli are rated as psychologically arousing. Some recent research has also pointed to a possible association between individual differences in interoceptive accuracy and the perception of time. The current experiment aims to assess the degree to which the effect of physiological arousal on time perception is moderated by interoceptive ability. We test this directly by measuring time production and time estimation under both low and high arousal. Interoceptive ability is estimated via a heartbeat counting task and it is predicted that this will moderate the relationship between arousal and timing. The impact of physiological arousal on time perception should be greater in individuals who are particularly attuned to their body (i.e. have high interoceptive accuracy). Initial findings will be presented.

Temporal estimation in prediction motion tasks is biased by a moving destination

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An ability to predict the time-to-contact (TTC) of moving objects that become momentarily hidden is advantageous in everyday life and could be particularly so in fast-ball sports. Prediction motion (PM) experiments have tested this ability using tasks where a target moves towards a stationary destination. Here, we replicated the classic PM experiment (Ram) and developed two novel versions in which the destination either moved away from (Chase) or towards (Attract) the moving target. The target and destination moved with different velocities such that collision occurred 750, 1000 or 1250ms after target occlusion. To determine if domain-specific experience conveys an advantage in PM tasks, we compared the performance of different sporting groups ranging from internationally competing athletes to non-sporting controls. There was no difference between sporting groups and non-sporting controls across all three PM tasks. In Ram, experimental manipulations had no meaningful effects on median response errors. In Chase and Attract there were significant and meaningful effects on response error by target velocity, destination velocity and occlusion period. To understand how the brain might estimate TTC when the target and destination are in motion, we present a model in which retinal input from the observed moving destination biases the internal representation of the velocity of the occluded target and thus the estimated TTC. This model closely reproduces the observed patterns of response error found in Chase and Attract.

Temporal estimation error with two moving objects persists across different stimulus properties

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Error in estimating the arrival time of an object that trails a lead object by a short delay is consistent with the well-known Psychological Refractory Period (PRP), and has been explained by attentional allocation rather than a capacity limitation. In the current study, we examined the influence of stimulus properties (vertical separation; object shape) on temporal estimation in a prediction motion task. For the baseline condition, participants observed two moving objects (7.5 and 5 deg/s), separated by 3 deg in the vertical axis, that approached a fixed location. They pressed keys (Y with right index finger; B with left index finger) to coincide with the objects arrival. The difference between the arrival times was ±250 ms or ±500 ms. In experimental conditions, the two objects were separated by 0.5 deg (Experiment 1) or were aligned in the vertical axis (Experiment 2). Results showed that participants were able to judge arrival order of the two objects with very high accuracy, except when the motion paths crossed during the occlusion interval with close temporal proximity to arrival. Moreover, in trials where arrival order was correctly judged, constant error was significantly higher for the object that trailed, as opposed to led, by 250 or 500 ms. Constant error was not correlated with measures of horizontal separation between the two objects. Taken together, our results indicate that the PRP effect in prediction motion is consistent with over allocation of attention to the leading and thus most salient object, irrespective of different stimulus properties and arrival times.

Judging the duration of painful and non-painful stimuli

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Pain has physiological and psychological consequences[1], notably interfering with cognition and distracting from ongoing tasks[2]. Previous work from our laboratory has shown a marked overestimation of presentation duration for stimuli associated with pain in comparison with stimuli associated with no-pain[3]. Pain therefore appears to lengthen the perceived duration of events. We report two experiments which further explore these effects by examining 1) the effect of pain intensity and 2) the effect of pain focus, on perceived duration. In Experiment 1, participants judged the duration of moderately painful, mildly painful and not painful electro-cutaneous stimulation (pain focus). The results showed that higher intensity stimuli were perceived as lasting for longer than low intensity stimuli. In Experiment 2, participants were placed in 2 minute states of moderate pain, mild pain or no pain using thermal stimulation. Whilst in these states participants judged the duration of neutral visual stimuli (pain background). The results showed that as the state of pain increased in intensity, duration judgements shortened. Pain therefore has opposing effects on duration processing depending on whether it is the focus of the duration judgment, or whether it is experienced concurrently in the background. Results are discussed in the Scalar Expectancy Theory framework[4].

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Temporal information in mild cognitive impairment

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Serial position effects refer to the observation that items learned at the beginning (primacy) and/or at the end (recency) of a list are remembered better than items in the middle. Older adults with cognitive impairment present a primacy deficit. We posit that by examining the order in which items are recalled, it is possible to understand the nature of this memory deficit. Bruno et al. (2016) showed that healthy older adults with intact cognition tend to recall words by preserving the temporal order of the study list. Our aim in this study was to determine 1) whether individuals with Mild Cognitive Impairment (MCI) showed poorer usage of the temporal order information compared to healthy peers, and 2) whether this low usage rate predicted general cognitive ability in MCI. Our sample comprised 104 individuals with MCI and 100 controls, all aged 50 or more. Global cognitive functioning was estimated with a composite score including performance on immediate and delayed memory, working memory, speed and flexibility, and verbal learning. Memory performance was measured with the Rey's AVLT. Our findings show that individuals with MCI employ temporal information less than their healthy peers, and that lower usage is linked with poorer cognitive ability. These findings demonstrate that measures of temporal cueing in recall tasks may be a valid marker of cognitive decline, which could be used for early detection of MCI.

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Group membership, implicit racial bias and dispositional empathy distort time perception.

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Group membership and negative social attitudes towards other races may influence emotional and cognitive reactivity to others. Here, we investigated whether racial differences, implicit racial bias and dispositional empathy modulate the ability to perceive the temporal outcome of complex motor sequence, such as handwriting. Thirty white participants were asked to predict the end of visually perceived 'human body motion', i.e. handwriting and 'biological dot motion' which was of the same prerecorded hand movement. Importantly, the hand performing the

writing action belonged to either to an ingroup (white) or to an outgroup (black) model. Participants were presented with the two types of videos, which were interrupted after a variable interval ('pre-dark') from its onset by a dark interval of variable duration (6, 9 and 12 sec). During the 'dark' interval, participants were asked to indicate when the movement represented in the video reached its end by clicking on the space bar of the keyboard. During the early target interval, participants exhibited greater time (over)estimation in the 'human body motion' condition when the handwriting movement was performed by the white ingroup model as compared to the outgroup and control condition. Interestingly, interindividual differences in levels of empathic traits and implicit racial bias modulated participants' temporal expectation so that lower time estimation for the outgroup model was related to low level of empathic concern and high level of racial bias. Our findings suggest that temporal expectation likely linked to predictive embodied simulation of ingroup racial members' movements is affected by cultural and dispositional interindividual differences.

Unpacking the prediction-motion literature

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In a *Prediction Motion* (PM) task, participants observe a moving target disappear behind an occluder, and press when it reaches a goal. I have attempted to review and consolidate the fragmented PM literature by elucidating four theoretical dichotomies, and answering them with new data. **Dichotomy 1)** Do people track the occluded target with spatial attention (tracking strategy), or estimate time-to-contact before occlusion, then delay a motor response (clocking strategy)? Answer: Tracking and clocking are both viable strategies. **Dichotomy 2)** Is PM mediated by mental imagery, or the oculomotor system? Answer: Neither. **Dichotomy 3)** People can do PM tasks in physical space and feature space. They may thus update mental representations, both without sensory input, and at the right speed. Do we have a *common rate controller* in the brain, which can be functionally coupled to different sensory maps, or does each map have its own local rate control circuitry? Answer: common rate controller. **Dichotomy 4)** Do people run a rate controlled simulation of the occluded process, or do they use a clocking strategy? Answer: common rate controller. This synthesis helps unpack the PM literature, but also offers a new way of understanding fundamental mechanisms involved in controlling thought and action.

Examining visual complexity and its influence on perceived duration

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We investigated whether visual complexity of novel abstract patterns affects perceived duration. Previous research has reported that complex visual stimuli led to an underestimation of durations. However, to clarify the nature of the time estimation process, it is necessary to establish which component of image complexity, spatial or semantic, plays the critical role. Here we tested the impact of specific spatial properties. We used unfamiliar and abstract patterns made using black-and-white checkerboards in which the difference between stimuli was exclusively in configuration. Visual complexity was quantified by the GIF index based on a compression algorithm, which scanned the pattern in both horizontal and vertical directions. This metric correlated positively with subjective complexity (Experiment 1A). In the second study, we increased variability in the stimuli by changing the number of items across patterns

while keeping overall size constant. A high positive correlation was found between objective and subjective complexity (r = 0.95) (Experiment 2A). In Experiments 1B and 2B, observers estimated pattern durations in seconds using a continuous scale. A multilevel linear analysis found that perceived duration was not predicted by visual complexity for either of the two sets of stimuli. These results provide new constraints to theories of time perception, hypothesizing that complexity leads to an underestimation of duration when it reduces attention to time.

Does Preference for Abstract Patterns Relate to Information Processing and Perceived Duration?

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Repetitive prestimulation, in the form of click trains, is known to alter a wide range of cognitive and perceptual judgments. To date, no research has explored whether click trains also influence subjective preferences. This is plausible because preference is related to perceptual fluency and clicks may increase fluency, or, because preference is related to arousal and clicks may increase arousal. In Experiment 1, participants heard a click train, white noise, or silence through headphones and then saw an abstract symmetrical pattern on the screen for 0.5, 1, or 1.5 s. They rated the pattern on a 7-point scale. Click trains had no effect on preference ratings, although patterns that lasted longer were preferred. In Experiment 2, we again presented a click train, silence, or white noise but included both symmetrical and random patterns. Participants made both a duration and a preference judgment on every trial. Auditory click trains increased perceived duration, and symmetrical patterns were perceived as lasting longer than random patterns. Again there was no effect of auditory click trains on preference, and again patterns that were presented for longer were preferred. We conclude that click trains alter perceptual and cognitive processes, but not preferences. This helps clarify the nature of the click train effect and shows which predictions implicit in the existing literature are supported.

Neural mechanisms of affective touch processing

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A sub-population of touch sensitive nerves called C-Tactile afferents (CTs) have been identified in the hairy, but not glabrous skin of humans. CTs respond optimally to slow moving (~3cm/sec), gentle touch and their discharge frequency is positively correlated with ratings of pleasantness. It is proposed that these fibres encode the socially rewarding aspects of touch during affiliative and nurturing interactions. The aim of the current study was to determine how individuals process CT-optimal and non-CT-optimal touch and the corresponding differential neural activity measured using EEG. Previous research has shown an ultra-late evoked potential, measured specifically for CT-optimal stroking and comparable to similar salient stimuli such as pain. Twenty-one individuals aged 18-40 completed an EEG study. During the study participants received soft brush strokes to their right arm at CT-optimal (3cm/sec) and non-CT-optimal (30cm/sec) velocities, delivered manually by the researcher. Here we will also examine for and present evidence related to ultra-late evoked potential to non-CT-optimal stroking to determine the specificity of neural signatures for the processing of CT mediated affective touch. It is anticipated that CT-optimal touch will result in an ultra-late evoked potential representative of

reward/affect processing associated with CT-optimal touch, compared to activity measured during non-CT-optimal touch.

The effect of listening demand on effort-driven cardiac response.
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Despite a considerable number of empirical articles, the evidence in support of the physiological measures used to quantify listening effort is inconclusive and unsupported by psychophysiological theories or theories about effort. This study delivers a systematic examination of the link between autonomic nervous system activity and listening effort, guided by the framework of motivational intensity theory. We examined sympathetic and parasympathetic driven cardiovascular responses associated with listening effort including pre-ejection period (PEP), blood pressure, heart rate and high-frequency heart rate variability (HF-HRV). It was predicted that listening effort (operationalised as cardiovascular response) would change as a function of the difficulty to understand speech (listening demand). Additionally, it was expected that the observed change in cardiovascular activity would be associated with higher ratings of subjective effort and fatigue. Eighty-four adults with normal hearing were randomly assigned to three conditions of a speech recognition task (listening demand: easy, moderate vs. high). The participants performed thirty trials of the task following a habituation period. Planned contrasts revealed a positive linear effect of task difficulty on subjective effort ratings, as well as the reverse effect on task performance. Although no effects of listening demand were initially found for the specific indicators of parasympathetic (HF-HRV) and sympathetic (PEP) activity, planned contrasts revealed that systolic blood pressure (SBP) increased proportionately with listening demand. Also, in a secondary analysis, parasympathetic activity (HF-HRV) was significantly reduced in the high demand condition compared with collapsed data from the easy and moderate conditions. These findings are congruent with previous research which also shows that SBP and HF-HRV respond sensitively to task demand. As well as demonstrating that effort-driven cardiovascular responses increase as a function of listening demand.

An experimental investigation of pain in autism: A QST approach.
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Background: Paired with the adverse lifelong effects of communication, socialization and restrictive/repetitive behaviours, in Autism, are sensory perceptual anomalies; including a change in pain experience. This evidence has generally arisen from, and relies upon, case studies, self- and parent-report. Despite the limitations of these approaches, the presence of pain insensitivity in ASD has been given further validation because of its inclusion as a feature in diagnostic texts; the current DSM-V includes the domain of "hyper- or hypo reactivity to sensory input". However, there is a dearth of rigorous experimental evidence to support these claims. To date 6 studies have utilised experimental paradigms to better understand the pain experience of individuals with Autism, specifically employing recognised psychophysical protocols. Results are inconsistent, however, do provide tentative insight into the possibility that the sensory abnormalities mentioned by the DSM can be quantified, but more investigation is required. Standardised Quantitative Sensory Testing; a modern reliable psychophysical test of large and small-fibre (each involved in aspects of pain experience) sensory modalities, can in-fact provide such quantification. Aims: To establish if individuals with autism experience pain

differently to healthy controls, through a general autistic phenotype study and then in a clinical population of individuals with autism. Methods: A standardised Quantitative Sensory Testing protocol; as defined by the German Research Network on Neuropathic Pain (DFNS, Rolke et al. 2006), was utilised to gain the sensory profiles of 52 individuals. This battery consists of 7 tests measuring 13 parameters for both pain and sensation, including thermal, mechanical and pressure modalities. Additionally, participants completed the Autism Quotient. The same battery is then used for individuals with Autism (N=6) for which preliminary HC group comparison data is presented. Results: There was no significant group difference in sensory testing for borderline or strong likelihood of autism, autistic traits and average or low autistic traits, as measured by the Autism Quotient, with the exception of mechanical detection threshold. No significant group differences between individuals with a diagnosis of autism and matched healthy controls. Conclusion: These results do not support the current perspective of anecdotal evidence, which the current diagnostic texts have already adopted. Sensory processing anomalies do not appear to be predicted by severity of autistic traits. However, there is tentative indications that a clinical presentation of autistic traits (as measured by an AQ score above 26) predicts alterations in measures of light touch.

Neuroenhancement Strategies: Prevalence and associative factors in UK universities.

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Neuroenhancement (NE) strategies are techniques implemented by healthy people to enhance their cognitive performance or mood. A popular technique for NE is the use of pharmacological agents, and many products have been used for these purposes, including caffeinated products, medicines, herbal products, and controlled drugs. Recently, there has been a reported increase in the use of these agents in the USA and Europe, with studies into this phenomenon focusing primarily on prevalence and efficacy. Additionally, there has been emphasis on NE drug use in academic populations, specifically students studying at university, as these drugs are perceived as improving study skills and working practices. However, speculative reporting in the media has led to many untested claims about the extent of use and the benefits that might result from use of these substances. Nevertheless, this has led to debates concerning the safety of use, appropriate policy responses, and ethical implications of use including questions on academic competitiveness and advantage. We will review data from a mass online survey which investigates prevalence of pharmacological neuroenhancers in UK university students and subgroups; summarise findings on the uses of these agents, and factors associated with their use.

Exploring the Effects of Acute Tryptophan Depletion on Taste Perception

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It has long been accepted that individuals with depression suffer from a change in taste perception and pleasantness. With the recent research revelation that specific tastes evoke the release of serotonin, a derivative of tryptophan, from taste cells it could explain the change in taste perception found in depressed people. Through the use of acute tryptophan depletion (ATD) on healthy individuals the production of serotonin is prohibited and as such allows for

the exploration of the role it plays in taste perception. Participants were screened prior to participation using the SCID assessing the presence of Axis I disorders and were excluded from participation if they met the requirements for any of disorders covered by the interview. Twenty five participants underwent a double blind study consisting of 2 sessions; control and ATD. During each session participants were given four different tastes; sweet, sour, salty and bitter all at a range of concentrations that increased in half-log steps. Taster status was also established through the use of a PROP soaked filter paper. Results indicated no significant effect for taster status on the perception, intensity or pleasantness of the tastes; however significant differences were noted between the sessions for bitter taste detection at high concentrations with detection ability increasing with ATD. Sour intensity at mid-range concentrations and bitter intensity are high concentrations also increased in intensity ratings during the ATD session and bitter tastes from mid-range to high concentrations were considered significantly less pleasant during the ATD session. This suggests that it might not be role of serotonin plays in taste perception that alters the taste changes in depressed individuals.