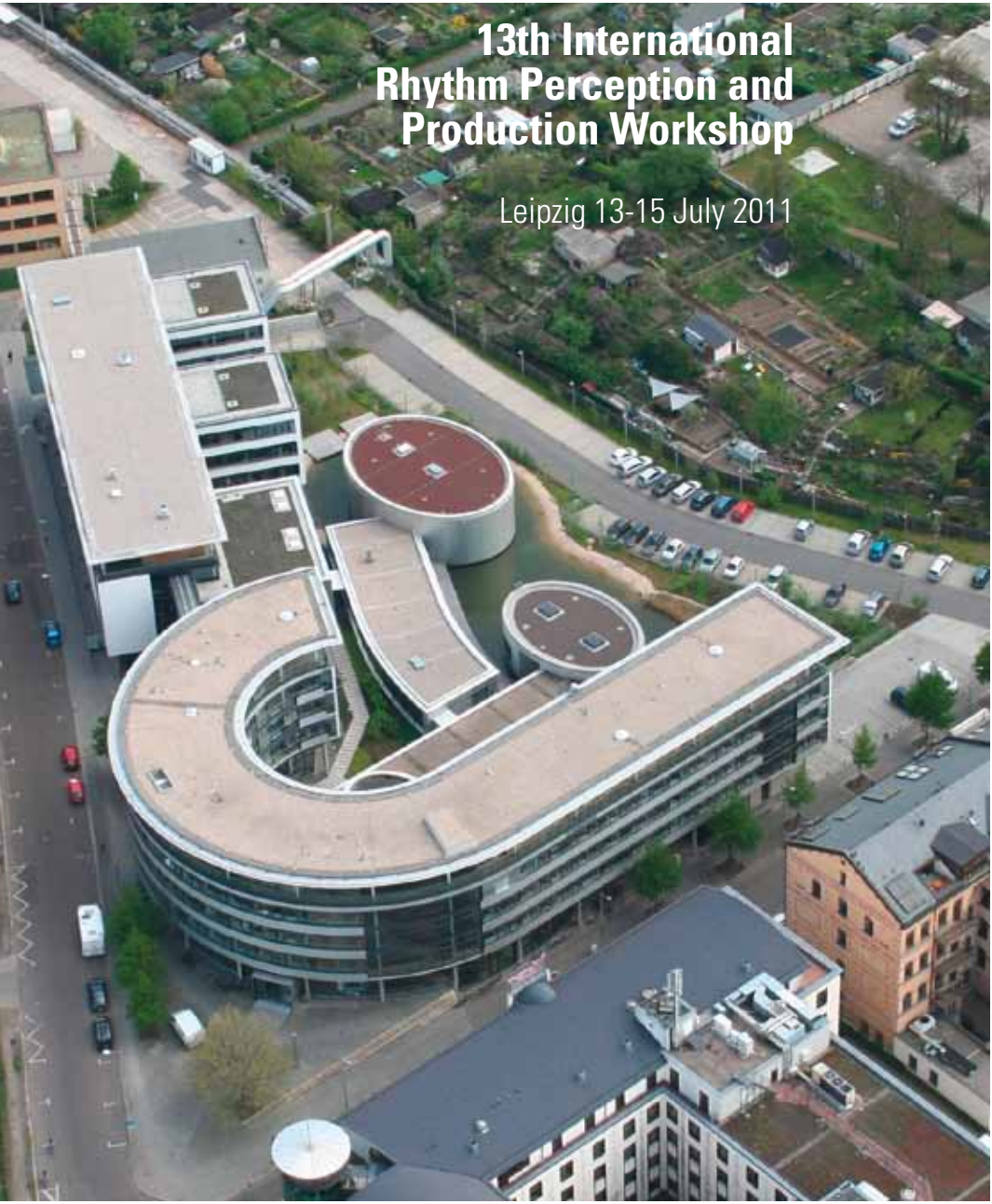
MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCE LEIPZIG

13th International Rhythm Perception and Production Workshop

Leipzig 13-15 July 2011



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PROGRAM

Organizing Committee

Peter Keller [1], Sonja A. Kotz [2], Michael Hove [1],
Assistant: Kerstin Träger

Scientific Committee

Fred Cummins, Sofia Dahl, Simone Dalla Bella, Yvonne Delevoye, Henkjan Honing, Michael Hove, Peter Keller, Sonja A. Kotz, Ralf Krampe, Yoshitaka Nakajima, Bruno Repp, Leon van Noorden, Dirk Vorberg, Alan Wing

[1] Max Planck Research Group, Music Cognition & Action, Leipzig
[2] Minerva Research Group „Neurocognition of Rhythm in Communication“, Leipzig

Wednesday July 13, 2011

08:45-09:00 **Registration**

09:00-09:15 **Welcome** Peter Keller

09:15-09:45 **Is hierarchy in rhythm perception consciously learned?**
Henkjan Honing, Fleur Bouwer

09:45-10:15 **Implicit learning of between-group IOIs in a complex temporal structure**
Josephine Terry, Catherine Stevens, Barbara Tillmann

10:15-10:45 **Inter-individual differences in auditory learning of piano sequences and white matter fiber tract architecture**
Annerose Engel, Brenda Hijmans, Leonardo Cerliani, Peter E. Keller, Marc Bangert, Christian Keysers

10:45-11:10 Coffee Break

11:10-11:40 **Processing and representing temporal patterns in the brain: A classifier and scaling analysis**
Hiroshige Takeichi, Yoshitaka Nakajima, Takako Mitsudo, Shozo Tobimatsu

11:40-12:10 **Neuroelectric correlates of the P-centre**
Rudi Villing

12:10-12:40 **Distinct neural substrates of duration-based and beat-based auditory timing**
Sundeep Teki, Manon Grube, Sukhbinder Kumar, Timothy D. Griffiths

12:40-14:00 Lunch - Hang up posters

14:00-14:30 **Spectral fluctuation in music shapes movement synchronization**
Birgitta Burger, Marc R. Thompson, Geoff Luck, Suvi Saarikallio

14:30-15:00 **Tagging the neuronal entrainment to beat and meter with steady-state evoked potentials**
Sylvie Nozaradan, Isabelle Peretz, André Mouraux

15:00-15:30 **Synchronizing with regular and with aksak rhythms**
Hans-Henning Schulze, Sina Schulte, Dirk Vorberg

15:30-16:00 Coffee Break

16:00-16:30 **Timing in continuous drawing task: could it be more explicit?**
Jacques Larue

16:30-17:00 **Using changing anisochrony in a sensorimotor synchronisation paradigm to investigate error correction and long-term memory**
Jacques Launay, Roger T. Dean (Presenter), Freya Bailes

17:00-17:30 **Neurophysiology of temporal processing during a synchronization-continuation tapping task**
Hugo Merchant, Wilbert Zarco, Ramon Bartolo, Luis Prado

17:40-19:00 **Poster Session*** (see below for titles), with refreshments

*posters can remain posted for the duration of the workshop

09:15-09:45 **Are the perceived characteristics of speech as it is produced used for immediate feedback control or learning of speech-motor targets?**
Peter Howell

09:45-10:15 **The effects of motor and cognitive fatigue on timing capacities**
Yvonne Delevoye-Turrell, Gaetan Agneray

10:15-10:45 **Tapping in rhythm on visually unrelated targets**
Anne Giersch, Hélène Wilquin, Yvonne Delevoye-Turrell

10:45-11:10 Coffee Break

11:10-11:40 **A more realistic two-level timing model with reafferent feedback loop**
Dirk Vorberg

11:40-12:10 **Violation of the scalar property for time perception between 1 and 2 seconds: Evidence from interval discrimination, reproduction and categorization**
Simon Grondin

12:10-12:40 **A neurodynamic model of musical timing**
Edward Large

12:40-14:00 Lunch

14:00-14:30 **"Beating together": Evidence that entrainment and affiliation mutually affect each other**
Martine Turgeon

14:30-15:00 **Effects of personality on synchronization to music**
Geoff Luck, Suvi Saarikallio, Birgitta Burger, Marc R. Thompson

15:00-15:30 **Ensemble timing in string quartet performance**
Alan M Wing, Satoshi Endo, Adrian Bradbury, Dirk Vorberg

15:30-16:00 Coffee Break

16:00-16:30 **Top-down anticipatory effects on MMN highlight prediction-based modification of initially stimulus-driven rhythmical pattern perception**
Alessandro Tavano, Michael Schwartze, Erich Schröger, Sonja A. Kotz

16:30-17:00 **Silent articulation modulates beat perception**
Molly J. Henry, J. Devin McAuley

17:00 Short Break

17:15-17:45 **Time to strike. Effects of movement pattern on variability in timing and sound level in drumming**
Sofia Dahl, Michael Grossbach, Eckart Altenmüller

17:45-18:15 **Anticipatory phase correction in sensorimotor synchronization**
Bruno H. Repp, Gordon P. Moseley

19:00 Conference Dinner at Bayerischer Bahnhof
(Bayerischer Platz 1, see map on the cover)

Friday July 15, 2011

09:15-09:45 **An examination of errors during sustained aperiodic synchronization among speakers**
Fred Cummins

09:45-10:15 **Acoustic correlates of speech rhythm: How well do durational characteristics of consonantal and vocalic intervals represent sentence rhythm?**
Volker Dellwo

10:15-10:45 **The effect of synchronous reading on speech rhythm**
Michael O'Dell, Tommi Nieminen, Liisa Mustanoja

10:45 Coffee Break

11:10-11:40 **Conveying syncopation in music performance**
Dirk Moelants

11:40-12:10 **Rhythm and meter as compositional ‚footprints' in 19th century art songs**
Leigh Van Handel

12:10-12:40 **An auditory illusion of infinite tempo change and some of its applications**
Guy Madison

12:40-14:00 Lunch

14:00-14:30 **Rhythm phenomena in rap music**
Igor Jauk, Petra Wagner, Bernd Möbius

14:30-15:00 **Multidimensional scaling of poetic rhythm patterns: gender-specific**
Anatole Fiodorov

15:00-15:30 **Neural correlates of meter and rhyme in poetry**
Sonja A. Kotz, Tim Raettig, Martin von Koppenfels, Winfried Menninghaus

15:30 Closing remarks, Sonja A. Kotz

Posters

- **Measuring the Rhythmic Properties of Eye Movements**
  Rasmus Bååth, Thomas Strandberg, Guy Madison

- **fMRI Study of Sensorimotor Synchronisation when Stimuli Induce Internal Pulsation or Not**
  Michael De Pretto, Claude-Alain Hauert

- **Temporal units in Russian read speech**
  Olga I. Dioubina-Reubol

- **Using spatio-temporal tapping to measure executive functions**
  Mariama Dione, Laurent Ott, Yvonne Delevoye-Turrell

- **Role of the dorsal premotor cortex in rhythmic auditory-motor entrainment: a perturbational approach by rTMS**
  Fabio Giovannelli

- **Entrainment in Language and Music: Dissociating Meter from Periodicity**
  Eleanor Harding, Daniela Sammler, Sonja A. Kotz

- **Interacting with non-responsive and responsive tapping partners**
  Tommi Himberg

- **Multiple-look effects on temporal discrimination within sound sequences**
  Gert ten Hoopen, Stéphanie van den Berg, Jiska Memelink, Bruno Bocanegra, Roel Boon

- **Audio- and Visuo-Motor Synchronization with Discrete and Continuous Stimuli: An fMRI study**
  Michael Hove, Merle Fairhust, Sonja A. Kotz, Peter Keller

- **Hear it low and slow: bidirectional pitch changes differentially influence the perception of interval duration**
  Jessica I. Lake, Kevin S. LaBar, Warren H. Meck

- **The Rhythm and Meter of Nursery Rhymes are Reflected in Patterns of Slow Amplitude Modulation (AM) in the Acoustic Signal**
  Victoria Leong, Richard Turner, Usha Goswami

- **Mechanisms of interpersonal coordination in duet music performance**
  Janeen Loehr, Caroline Palmer

- **The role of multiple rhythmical levels in the perception of music: Judgments of speed increase with event density**
  Guy Madison, Johan Paulin

- **Interactive rhythmic auditory stimulation reinstates 1/f timing in gait of Parkinson's patients**
  Yoshihiro Miyake, Michael Hove, Kazuki Suzuki, Hirotaka Uchitomi, Satoshi Orimo

- **The role of conscious and automatic processes in temporal prediction during sensorimotor synchronization**
  Nadine Pecenka, Peter Keller

- **How do we measure rhythm? An explanatory approach to speech timing**
  Tamara Rathcke, Rachel Smith

- **Evidence of metric and syntactic violation detection among Spanish late learners of German: An ERP study**
  Maria Paula Roncaglia, Maren Schmidt-Kassow, Sonja A. Kotz

- **Sensormotor synchronization and its influence on the auditory processing of deviance**
  Michael Schwartze, Maren Schmidt-Kassow, Sonja A. Kotz

- **Effect of beat isochrony and motor entrainment on music performance in a child drummer prodigy**
  Jakub Sowiński, Nicolas Farrugia, Simone Dalla Bella

- **Hearing the speed of the moving dots: visual motion biases non-spatial auditory tempo perception**
  Jasmine Su, Donatas Jonikaitis, Ernst Pöppel

- **Effect of pattern complexity and expertise on movement kinematics during perception and reproduction of auditory rhythms**
  Giulio Tirinelli, Marc Thompson, Geoff Luck, Petri Toiviainen, Marta Olivetti Belardinelli

- **The influence of environment and music on walking speed and step tempo of pedestrians**
  Leon van Noorden, Marek Franek

Abstracts

Abstracts (In Alphabetical Order by Author)

Measuring the Rhythmic Properties of Eye Movements

Rasmus Bååth[1], Thomas Strandberg[1] and Guy Madison[2]

The aim of this study was to investigate if, and how well, subjects synchronize their eye movements to a given rhythm. Subjects (n=18) were given the task of shifting their gaze between two horizontally aligned fixation points in the tempo of an isochronous beat. The beat was given by 50 msec square wave beeps of 440 Hz with inter-onset intervals (IOI) of either 0.5 or 1.0 sec. Each subject was recorded during 16 session of 30 sec each. Gaze position was recorded using a high-speed eye tracker with a temporal resolution of 500 Hz. Fixation onsets for the two fixation points were calculated from the gaze position data.

A measure of accuracy is the absolute difference between beep onsets and fixation onsets. This was found to differ significantly from zero with a mean of 137 msec. Mean asynchrony over all subjects also differed significantly from zero with a mean of -50 msec. This is comparable to the negative mean asynchrony of 20-80 msec frequently found in finger tapping tasks. The mean of the SDs of subjects' asynchronies was 157 msec. There was a significant effect of IOI on accuracy where the 0.5 sec IOI yielded a more accurate response. No significant correlation between reported number of years of musical training and accuracy was found. This study show both similarities and differences between rhythmic synchronizing of eye movements and finger taps and opens up the field for further study on rhythmic eye movements.

[1] Lund University Cognitive Science, Lund University, Lund, Sweden

[2] Department of Psychology, Umeå University, Umeå, Sweden

Spectral fluctuation in music shapes movement synchronization

Birgitta Burger[1], Marc R. Thompson[1], Geoff Luck[1], Suvi Saarikallio[1], and Petri Toiviainen[1]

Music makes people move. However, it still remains unknown why people respond to music with spontaneous movements often being periodic and synchronized. This study aims at investigating synchronization to music-induced movement, particularly in relation to the musical content. 60 participants were asked to move to 30 short excerpts of popular music while being recorded with an optical motion capture system. Subsequently, the periodicities of seven body parts (left hip, ankles, neck, wrists, and right shoulder), represented in a local coordinate system, were analyzed for each performance using auto-correlation. Next, we calculated the synchronization error relative to four different metrical levels (half, one time, two times, and four times the beat period) of the excerpts. These data sets were then correlated with 13 spectro-temporal features derived from the excerpts. Results suggest that flux in the lower (50-200 Hz) and higher frequency bands (3200-6400 Hz) influence synchronization accuracy in two distinct ways. Low sub-band fluxes were found to correlate positively with the synchronization error of wrists, hip, neck, and shoulder, suggesting that the more changeability there was in low frequencies, the less accurate participants were synchronized in these body parts. On the other hand, negative correlations were found between high sub-band flux and the synchronization error of hip, left ankle, neck, shoulder, and right wrist, suggesting that participants were better synchronized with strong high-frequency fluctuation. Furthermore, the higher the metrical level, the larger number of body parts showed significant positive correlations ($p<0.05$) with the synchronization error, indicating that high levels of low-frequency flux decreases synchronization accuracy more efficiently for the higher metrical levels than for the lower ones. Additionally, lower metrical level yielded a larger number of significant negative correlations between high sub-band flux and body parts, suggesting that strong high-frequency flux affects synchronization accuracy especially in the lower metrical levels.

[1] Finnish Centre of Excellence in Interdisciplinary Music Research, University of Jyväskylä, Jyväskylä, Finland

An examination of errors during sustained aperiodic synchronization among speakers

Fred Cummins[1]

Joint rhythmic action can be regarded as a form of entrainment among actors, temporarily establishing a supra-personal domain of relative autonomy among coordinated individuals. Entrainment-based accounts of joint action typically rely heavily on phase measurements to describe relative coordination, and phase modulation is the principal means by which synchronization is achieved. While this account may provide a useful description of dancing, clapping, and other periodic activities, it is still incomplete when describing the sustained aperiodic synchronization observed when two speakers read a text in synchrony, as there is no obvious definition of phase, and hence no clear means for sustaining phase-based entrainment. TMS studies1 have shown, however, that listeners to speech exhibit subliminal muscle activation that functionally mirrors the activity of the speaker, suggesting a possible basis for entrainment during aperiodic speaking. We here examine a corpus of speech errors occurring during the synchronous reading of word lists. Errors during joint reading display characteristics that are often quite distinct from those observed when reading alone. Abrupt cessation of all speaking activity as a direct result of an error by one speaker is relatively frequent. In other cases, joint activity is sustained in spite of considerable temporal and segmental mismatch among speakers. The pattern of results will be examined to see if they are compatible with an entrainment-based account that views synchronized speaking as the establishment of a transient domain of relative autonomy, vulnerable to perturbation, and sometimes to destruction, by speech errors.

[1] University College Dublin, Dublin, Ireland

Time to strike. Effects of movement pattern on variability in timing and sound level in drumming.

Sofia Dahl[1], Michael Grossbach[2] and Eckart Altenmüller[2]

Drummers are expert tappers, highly trained to minimize temporal variability while controlling sound level. As percussion instruments have a wide dynamic range, a player needs to have detailed control of the movement of the stick in order to play strokes with similar sound characteristics and loudness. Furthermore, certain combinations of tempo and dynamic level are likely to be more difficult to control because of the inherent dynamics of the stick and drum head.

In this work, we investigate how produced sound level and timing in continuous drumming is influenced by players' stick control. To this aim, we recorded movement and acoustical data of four professional percussionists playing single strokes at different tempi (50, 120, 300 bpm) and dynamic levels (p, mf, f). The timing of strokes was measured from the electrical contact between a thin copper foil at the tip of the drumstick and a circle on the drumhead sprayed with a thin graphite layer.

The movement analysis concentrated on the vertical displacement of markers on the players' hand, and stick (the vertical acceleration being the most important to transfer energy at impact). The preparatory movement time was calculated as the time from the highest peak of different markers before stick impact.

As expected, results show individual differences both in terms of range and variability for the measures studied. Not surprisingly, variability increased for extreme tempi, with the largest timing variability at 300 bpm played with the non preferred (left) arm. Preliminary results show that strokes played at mf 50 bpm were, on average, louder compared to mf strokes at medium and fast tempi. The longer preparatory movement time could indicate that players chose to use the additional time between strokes to increase their dynamic range.

[1] Aalborg University Copenhagen, Copenhagen, Denmark

[2] Hanover University of Music, Drama and Media, Hanover, Germany

fMRI Study of Sensorimotor Synchronisation when Stimuli Induce Internal Pulsation or Not.

Michael De Pretto[1], Claude-Alain Hauert[1]

Using functional magnetic resonance imaging (fMRI), the present study focuses on cerebral correlates to sensorimotor synchronization (SMS). The cerebral structures most cited for their implication in motor temporal regulation are the cerebellum (e.g. Molinari et al., 2007), basal ganglia (e.g. Harrington et al., 1998) and the supplementary motor areas (SMA, e.g. Jäncke et al., 2000). The exact role of these different structures is still not clear.
Brief tones where presented to participants in a succession of short-long intervals. Participants taped in synchrony with the second tone of the short interval, which was always 300ms long. In a regular condition, the long interval was twice the length of the short one. An irregular condition consisted of long intervals of mean duration twice as long as short intervals, with a range of ±20%. In the regular condition, participants had to tape every 900ms. In irregular condition, they had to tap 300ms after first sound of short interval. Both conditions imply timing, feedback and error correction. Only regular condition induces an internal rhythm.
Synchronisation error between tone and finger taps didn't show significant differences between conditions in mean nor in standard deviation, denoting equal level of difficulty between both conditions. All condition showed expected brain activations including left primary motor cortex and bilateral SMA, auditory cortex, basal ganglia and cerebellum. Comparisons between conditions didn't show any significant difference, surprisingly suggesting that the sensorimotor system did not take advantage of temporal regularity. Alternately, the results could suggest that tempo is processed in low level cerebral regions.

[1] Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland

The effects of motor and cognitive fatigue on timing capacities

Yvonne Delevoye-Turrell[1], Gaetan Agneray[1]

Spontaneous tempo, as determined from subjects freely tapping out a rhythm with their finger, was measured in 30 healthy adults and found to average 2 Hz, which confirms many previous studies (e.g., Collyer, Broadbent, and Church 1994). In the present study, we further investigated the functional role of spontaneous tempo by analysing the possible correlation between spontaneous tempo and synchronisation capacities, before and after a session of cognitive (N=15) and physical (N=15) fatigue.

After recording spontaneous tempo during two 40-second periods, subjects were required to produce a rhythmic tapping task in synchrony with an auditory BIP. Nine phases of ISI (from 200 to 2000ms) were presented in semi-randomised order. A 2minute rest time was proposed every 3 ISI phase. Individual results were analysed and revealed that mean IRIs were not significantly different from target ISI. Most importantly, IRI variability followed a U modulation-shape, with the smallest IRI variability falling within that interval of spontaneous tempo.

The second part of the experiment lasted 30 minutes. The same subjects performed either a series of cognitive exercises (alternation of 5-minute mental arithmetic and 5-minute subtraction task) or a series of physical exercises (alternation of 5-minute push-ups and 5-minute weight lifting). After completing a questionnaire for subjective fatigue, subjects performed once again the spontaneous taping and the synchronisation task. Preliminary results suggest that cognitive and motor fatigue had inverse effects on spontaneous tempo, with an acceleration of tempi after physical fatigue. IRI variability was increased in both groups. Most importantly, in both groups, the dip in IRI variability was found to be within that interval of spontaneous tempo.

It is possible that preferred tempi enhance sensorimotor simulation of the beat frequency (Kornysheva et al. 2009), which in turn provides more accurate and stable sequential motor planning.

[1] University of Lille nord de France, Lille, France

Acoustic correlates of speech rhythm: How well do durational characteristics of consonantal and vocalic intervals represent sentence rhythm?

Volker Dellwo[1]

Durational characteristics of speech contribute to the percept of speech rhythm. The present research investigated which durational information is more salient in terms of the auditory impression of the rhythm of a sentence: (a) the durations of consonantal and vocalic intervals or (b) the durations of syllables. For a perceptual experiment, durational cues of seven German sentences produced by ten German speakers (five male, five female) were extracted under two different conditions. In condition I, consonantal intervals were turned into /s/-sounds and vocalic intervals into /a/-sounds (cv-delexicalization). In condition II, entire syllables were turned into /sa/ syllables with a generic durational /s/:/a/ ratio of 5.5:4.5 (sy-delexicalization). In a rating task 21 native listeners of German judged on a seven point scale for 140 delexicalized sentences (7 sentences * 10 speakers * 2 delexicalization conditions) how well they matched the auditory rhythm of their originals. Results revealed that sy-delexicalized stimuli are typically rated significantly higher than their cv-delexicalized peers. It was found that when syllabic cues, in particular the number of syllables in a sentence, were not obtainable from the cv-delexicalization, listener ratings were poor. The results imply that cv-delexicalization possibly makes rhythmic characteristics of speech salient that are typically not salient to the human ear in real speech. The impact of this on how listeners may perceive rhythmic differences between languages using cv-delexicalized speech will be discussed.

[1] University of Zurich, Zurich, Switzerland

Spatial tapping: a behavioural tool to reveal executive strategies for motor planning.

Mariama Dione[1,2], Laurent Ott[1,2], Yvonne Delevoye-Turrell[1,2]

Executive functions have been described as the ability to update information in working memory to formulate plans of actions and to monitor their efficient execution (Rabbitt, 2008). This ability requires two mutually opponent computations (Cools, 2006) : (1) cognitive stability, i.e. the capacity to maintain cognitive representations across time, and (2) cognitive flexibility, i.e. the capacity to alterate these representations in response to changing environmental demands. The available cognitive resources may determine the prior use of either computations. In the present study, we asked subjects to perform a sequence of pointing movements following specific temporal constraints, to reveal the prior computation used for motor planning.

Six targets were displayed on a tactile screen to form a hexagonal figure. The subjects' task was to tap the targets one after the other in synchrony with an isochronous metronome. Subjects were required to be as accurate as possible in time. The tempo increased from one trial to the next, stepwise by increments of 100 ms. Subjects started with the slowest tempo (ISI = 1200 ms) and finished with the fasted tempo (ISI = 200 ms).

Results showed that three different behavioural strategies were used in order to maintain temporal accuracy. Indeed, the contact time variability decreased following three specific phases. In addition, the spatial error around each target was smaller for the two first phases (maintain strategy). In the last phase scatter plots of endpoint distributions around each target were systematically oriented towards the previous target (flexible computation without maintain). These results reveal updating processes based on (1) a high level of stability computation and a low level of flexibility for slow tempi ; (2) equal levels of stability and flexibility for intermediate tempi ; (3) low level of stability and a high level of flexibility for fast tempi.

[1] University of Lille Nord de France, Lille, France

[2] URECA University Charles-de-Gaulle Lille III, Villeneuve d'Ascq Cedex, France

Temporal units in Russian read speech

Olga I. Dioubina-Reubold[1,2]

In this study, the author compared relative durations within 3 types of temporal units. Temporal units were obtained from recordings of 15 speakers of Standard Russian of St.Petersburg reading a fable of about one minute length. The aim of the study was to find out whether distribution of temporal units in the speech sample under research is isochronic or not.

An island-driven method of segmentation was used to split temporal units into 3 data subsets in accordance with the following linguistic units: words with clear lexical stress, e.g. nouns, adjectives (subset 1), syntactic pauses and unstressed speech sequences spoken directly before or after these pauses (subset 2), unstressed function words in the enclitic position and their hosts (subset 3).

Durations of the distances between onsets of stressed vowels was computed relatively to the whole duration of the speech sample. Duration of non-speech material (pauses) was considered to be part of the rhythmical structure of the speech sample and was therefore included into the measurement.

Repeated-measures ANOVAs conducted for each of the subsets with 1) duration as dependent variable and 2) position of the units within the sentence as within factor revealed highly significant results ($p<0.001$) for the subset 3 (unstressed function words in the enclitic position and their hosts), significant results ($p < 0.01$) for the subset 2 (syntactic pauses and unstressed speech sequences spoken directly before and after these pauses), but no significant differences for the subset 1 (words with clear lexical stress), i.e. temporal units of the subset 1 show isochrony. This study confirms the dependence of isochronic or non-isochronic distribution of temporal units on the linguistic function of language elements constituting them.

[1] Department of germanic studies, University of Bamberg, Bamberg, Germany

[2] Institute of Phonetics and Speech Processing, University of Munich, Munich, Germany

Inter-individual differences in auditory learning of piano sequences and white matter fiber tract architecture

Annerose Engel[1,2,3], Brenda Hijmans[2], Leonardo Cerliani[1,2], Peter E. Keller[3], Marc Bangert[3], and Christian Keysers[1,2]

Complex interactions between cortical frontal motor areas, the cerebellum and basal ganglia take place during initial phases of motor learning. Specific motor skills, for instance those that characterize music performance, have been associated with differences in white matter fiber tracts connecting these areas. The present study examined relations between learning times for rhythmic piano tone sequences and differences in the integrity of white matter fiber tracts connecting frontal motor areas with a) the basal ganglia and the cerebellum; and b) parietal and temporal areas. Participants (n=18) were healthy, musically naive volunteers. Over three days of motor training they learned to play three melodies (i.e., seven keystrokes in specific rhythms) with their right hand on a piano keyboard under pure auditory instruction and feedback conditions (vision of their own fingers was occluded). Initial inter-individual learning times on the first training day ranged from 17 to 120 minutes (mean: 62 ± standard deviation: 29 minutes). Participants were divided into groups of fast and slow learners (each n=9). Anatomical white matter connectivity was measured using Diffusion Tensor Imaging. Tensor-derived indices of white matter microstructural features, such as fractional anisotropy (FA), were examined. Fast compared to slow learners showed higher FA values in the bilateral corticospinal tracts, which connect frontal motor areas and the cerebellum, and the right medial cerebellar peduncle, which is the input pathway to the lateral hemispheres of the cerebellum. Furthermore, higher FA values for fast compared to slow learners were found in the bilateral superior longitudinal fasciculi, a pathway interconnecting frontal, parietal and temporal areas. These results suggests that variability in white matter fiber tracts, connecting brain areas functionally relevant for motor learning, determine the speed with which novel complex sensorimotor skills, such as temporally precise piano performance, can be acquired.

[1] The Netherlands Institute for Neuroscience, Amsterdam, the Netherlands

[2] Department of Neuroscience, University Medical Center Groningen, Groningen, the Netherlands

[3] Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

Multidimensional Scaling of Poetic Rhythm Patterns: Gender-Specific

Anatole Fiodorov[1]

The aim of the current study was to determine the factors of poetic rhythm variation. This study made use of multidimensional scaling techniques to analyse temporal and F0 patterns of a verse as produced by American male (10) and female (9) speakers. Pairwise comparisons of the speakers' patterns made it possible to locate them on the two-dimensional scale and match them with the results of cluster analysis. The results suggest that there are female and male versions of poetic rhythm production which differs from the poem author's rendering. The difference between these versions of readings are discussed in terms of semantic and expressive devices used by different speakers.

[1] Linguistics University, Minsk, Belarus

Tapping in rhythm on visually unrelated targets

Anne Giersch[1], Hélène Wilquin[2] and Yvonne Delevoye-Turrell[2]

Tapping a rhythm on distinct visual targets requires the processing of visual information. Planning such a sequence is facilitated when the two successive targets are part of the same object (Bekkering & Pratt, 2004). It is not clear, however, if the execution of the action is also affected, and what is required when tapping on two unrelated targets.

We proposed to study these questions by exploring the performance of patients with schizophrenia who are impaired at grouping unrelated targets (van Assche & Giersch, in press). We tested 16 patients with schizophrenia, 15 adolescents with a high risk of developing psychosis and matched controls. Targets were circles arranged around a virtual circle. Subjects were instructed to tap on each circle sequentially, by following a rhythm organized in pairs. Taps were separated by intervals of 300 ms in a pair, and 600 ms between pairs. Pairs of taps were executed either on circles visually grouped by a connector (within-group), or on unconnected targets belonging to distinct pairs (between-group). We compared performance with a neutral condition without connector.

Results showed that all groups followed the rhythm efficiently, although the ratio between short and long time intervals was slightly reduced in adult patients. For all subjects, contact durations were shorter on the first than on the second tap of a pair. In adult controls, this effect was small in the neutral condition, but larger whenever connectors were present (within-group and. between-group). In patients suffering from schizophrenia, the contrast between the first and second tap was identical to controls for within-group targets, but almost absent for between-group targets. In adolescents, connectors had only a slight impact. Overall, these results suggest that visual organization affects motor planning and execution of a rhythmic sequence in adults, attention being required in case of unrelated targets.

[1] INSERM

[2] University Lille Nord de France, Lille, France

Role of the dorsal premotor cortex in rhythmic auditory-motor entrainment: a perturbational approach by rTMS

Fabio Giovannelli[1,2], Iglis Innocenti[3], Simone Rossi[3], Alessandra Borgheresi[1], Aldo Ragazzoni[1], Gaetano Zaccara[1], Maria Pia Viggiano[2], and Massimo Cincotta[1]

Introduction Synchronization of body movements to an external beat is a universal human ability, which has also been recently documented in non-human species. The neural substrates of this rhythmic motor entrainment are still under investigation. Correlational neuroimaging data suggest an involvement of the dorsal premotor cortex (dPMC) and the supplementary motor area (SMA). Objectives To investigate the role of these cortical areas in auditory-motor interaction processes more specifically using a causal approach by repetitive transcranial magnetic stimulation (rTMS). Methods In twelve right-handed healthy volunteers, 1 Hz rTMS was delivered to different cortical areas using an established rTMS protocol which produces a focal suppression of cortical excitability outlasting the stimulation period. Subjects were asked to synchronize right index tapping with different rhythmic auditory cues and to continue reproducing the rhythm after cessation of the external cues. All tasks were performed at the baseline and immediately after the 15 min long train of rTMS. Results Accuracy of voluntary synchronization between rhythmic cues and right index finger tapping, as measured by the mean time lag (asynchrony) between the onset of motor and auditory events, was significantly affected when the right dPMC was transiently disrupted by 'off-line' focal rTMS. This effect was seen with metrical rhythms of different complexity, but not with non-metrical or isochronous sequences. Conversely, no change in rhythmic motor entrainment was observed with rTMS of the SMA, of the left dPMC or over the midline occipital control site. Conclusions The current data strongly support the view that the right dPMC is crucial for rhythmic auditory-motor entrainment in humans. This contributes to clarify the neurophysiological substrate of musical abilities and represents a potential tool to plan rehabilitative strategies based on auditory cues such as those used in Parkinson's disease.

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Violation of the scalar property for time perception between 1 and 2 seconds: Evidence from interval discrimination, reproduction and categorization

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According to the scalar property for time, the variability to time ratio should be constant. Three experiments tested the validity of this property in a restricted range of durations (standard values = 1, 1.3, 1.6 and 1.9 s). In each experiment, time intervals to be discriminated, reproduced or categorized were presented with 2, 4, or 6 brief and successive auditory signals marking 1, 3 or 5 intervals, respectively. In Experiment 1, participants were asked to indicate whether the interval(s) within a second series of sounds were shorter or longer than those of the first. In Experiment 2, the standard interval had to be reproduced. In Experiment 3, after ten presentations of the standard, participants had to categorize each comparison intervals as shorter of longer than the standard. In addition to showing that performance was generally poorer when only one interval was presented and remained about the same regardless of whether 3 or 5 intervals were presented (Experiments 1 and 3), the results demonstrated that the variability to time ratio is not constant across the standard interval conditions. Overall, the ratio is higher at 1.9 than at 1 s. This violation to scalar timing applies whatever the method used, and does not interact with the number-of-interval variable.

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Entrainment in Language and Music: Dissociating Meter from Periodicity

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Entrainment, or the internal synchronization to rhythmic regularity of an incoming sensorimotor signal, is accepted as a natural phenomenon occurring in music (Large and Kolen, 1994). Entrainment in speech perception is on the other hand controversial; periodicity is claimed to be the perceptual backbone of entrainment, with the consequence that entrainment could therefore not occur in a typically aperiodic signal such as spoken language (Patel, 2008). A limitation in neuropsychological studies comparing music and language perception thus far is the co-occurrence of periodicity and regular meter in musical stimuli, while the presence of periodicity and meter in speech is seldom addressed. In an on-going EEG study we compare within-domain periodic to aperiodic signals in music and spoken language, to see if the occurrence of entrainment is dependent on the periodicity in the auditory stream. Dissociated from periodicity will be the meter in the signal, or the alternating stressed-unstressed relationship among the perceptual beats in syllables or notes, to see if regularity of meter serves as an alternative source of entrainment. The chosen means to measure the entrainment effects is via modulation of syntactic processing components in a 2x2x2 factorial design, with factors Syntax (preferred vs. non-preferred), Periodicity (isochronous vs. non-isochronous), and Meter (regular vs. irregular). Facilitated processing of non-preferred ambiguity resolution is expected if subjects entrain to the periodicity or meter in the auditory signal.

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Silent articulation modulates beat perception

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Previous research suggests a role for premotor cortex in sequence timing and beat perception. In one such study, Grahn and McAuley (2009) showed increased left premotor activation in listeners with high beat sensitivity relative to listeners with low beat sensitivity. In other work, Schubotz and colleagues (Schubotz, 2007; Schubotz, Von Cramon, & Lohman, 2003) have implicated premotor regions involved in articulation in prediction of event timing in structured sequences. The current study provides further support for premotor involvement in beat perception by combining a selective motor adaptation paradigm (Glenberg et al., 2010) with an auditory tempo judgment task that is sensitive to individual differences in beat perception; specifically, responses to ambiguous test sequences provided a means to estimate the degree to which listeners perceived a beat that was implied, but not explicitly emphasized, by the temporal structure of the sequence. We hypothesized that selectively adapting premotor areas involved in articulation would decrease beat sensitivity. In two experiments, listeners silently mouthed the syllable "blah" for three minutes before completing the tempo task. In Experiment 1, the motor adaptation manipulation was within subjects; half of the listeners completed the motor adaptation phase prior to the first block of trials, and half prior to the second block of trials. In Experiment 2, the motor adaptation manipulation was between subjects. In both studies, evidence that motor adaptation reduced beat sensitivity obtained. In Experiment 1, a rebound in beat sensitivity was observed following motor adaptation, but only for individuals with already high sensitivity to the implied beat. In Experiment 2, a slightly larger rebound in beat sensitivity was observed for those individuals engaging in motor adaptation relative to individuals who did not. Taken together, the two experiments provide initial support for the hypothesis that selective adaptation targeting premotor areas involved in articulation modulates beat sensitivity.

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Interacting with non-responsive and responsive tapping partners

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Background

Sensorimotor synchronisation is extensively studied using individual participants, focusing the analysis on time-keeping and static measures of asynchrony. Recently, a number of studies on dyads have emerged, and the analysis methods for studying interaction have been developed. This study proposes circular statistics –based methods for investigating interpersonal entrainment and tests them in comparing tapping in human dyads and with non-responsive computer partners.

Methods

36 participants took part in pairs. They performed synchronisation-continuation tapping tasks using a MIDI drum. Depending on condition they would either tap with each other or with computer partners. The participants did not know which partner they were tapping with, but were instructed to be as accurate as possible and stay together with their partner. The computer partners were either metronomically accurate, or had variability in either phase or in phase and period. There were three different tasks: to tap an isochronous beat in synchrony, or in syncopation (alternating) with their partners, or tapping simple interlocking rhythms. Individual tapping consistency, tempo stability, and pair's relative phase stability were analysed using circular statistics.

Results

Tapping consistency and pair's relative phase stability were highest when tapping with another human, compared to even the metronomically accurate computer partner. The metronomic and phase variable computer partners were best partners for tempo stability, understandably since they produce no period errors and no tempo drift. The human pairs often drift out of the original tempo, but remain very closely in sync together.

Conclusions

Interpersonal entrainment, with mutual adaptation produces a tighter connection between tapping partners than what can be achieved with a computer partner. This suggests that studying the dynamics of this interaction in addition to timing and time-keeping would be vital for understanding the phenomenon of sensorimotor synchronisation. Using a range of circular methods helps to uncover all facets of tapping performance.

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Is hierarchy in rhythm perception consciously learned?

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Beat and meter induction are considered important structuring mechanisms underlying the perception of rhythm. In an earlier study we showed that hierarchical representations for rhythms are formed pre-attentively in the human auditory system (Ladinig et al., 2009), a study that was (partly) mirrored with 2-3 day old neonates (Honing et al. 2009). Using the same stimuli, but now using a priming paradigm, we currently investigate whether priming the auditory stimuli with either a duple or triple rhythm will influence inattentive perception of ambiguous rhythmic stimuli. We expect to show that hierarchical representations for rhythms are formed pre attentively in the human auditory system. And finally, we will reconsider these empirical data in the light of the question whether these hierarchical representations are emergent (are they a structural property of the stimuli themselves) or whether they are learned (a result of mere exposure to music)?

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Synchronizing with auditory and visual rhythms: A reassessment of modality differences with fMRI

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Previous brain imaging studies of sensorimotor synchronization (SMS) reveal different activation patterns for discrete visual (Flashes) and auditory (Beeps) stimuli; these activation differences parallel more stable synchronization with Beeps than Flashes. Recent behavioral evidence indicates that visuomotor synchronization improves with continuously moving stimuli. In this fMRI experiment, 14 participants tapped with a pacing sequence in a 2 (modality: auditory, visual) x 2 (stimulus pattern: discrete, continuous) design. Behavioral results indicate that SMS was most stable with Beeps, least stable with Flashes, and intermediate—and similar—for frequency modulated (auditory) Pitch Sweeps and an up-and-down (visual) Moving Bar. For the imaging results, the discrete-stimuli contrasts revealed modality differences in areas involved in timing and sensorimotor integration: Tapping with Beeps compared to Flashes yielded greater activation in the putamen, cerebellum, and parietal areas. Conversely continuous-stimuli contrasts between Pitch Sweeps and Moving Bar revealed modality differences in sensory areas, but not in timing or integration areas. Results indicate that modality differences in synchronization, and their underlying neural processes, depend less on the modality per se, and more on the reliability of perceptual information (cf. Ernst & Bülthoff, 2004). Moving visual information can induce rhythms and timing representations for visual and auditory modalities involve a common basis.

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Are the perceived characteristics of speech as it is produced used for immediate feedback control or learning of speech-motor targets?

Peter Howell[1]

Speakers hear their voice as they speak. They may use this information for: 1) on-going control of the voice; and 2) learning of new speech targets particularly during speech development. It is argued that these two aspects have different requirements so their processing needs to be kept distinct. For instance, a child needs to learn some speech sounds during development that they are not capable of producing. This shows that motor learning can take place in the absence of auditory feedback of the child's own voice about those sounds. On the other hand, empirical work and theoretical proposals about processing of on-going control information (EXPLAN) show that this uses a subset of the structures used in speech-motor learning (DIVA) which suggest some commonality in their processing.

Two sets of studies are reported in this talk. The first sought to identify what brain mechanisms are involved in feedback control by looking at the intercorrelations between feedback tasks and tasks that are know to involve specific brain structures. These studies show that feedback affects brain mechanisms not involved in language control. The second set of studies looks at perceptual learning of a speech contrast that is foreign to the person after experience producing this in conditions where immediate feedback of the speaker's voice is altered. The entire set of results is discussed in connection with alternative theories of speech production.

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Rhythm Phenomena in Rap Music

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Rap is a musical singing style providing a nice example for rhythmic entrainment between a driving oscillating system, the music, and a driven system, the performing artist. In this view, the artist en-trains to the perceived musical rhythm and produces speech output both rhythmically adequate and semantically coherent – especially when improvising. The aim of the present study is to reveal the relationships between musical and speech rhythm. For this purpose we analyze rhythm structures on two levels, a local and global level. The local level describes relationships between a single musical beat, e.g. produced by the base drum and a co-produced syllable. In this focus we compute (1) Beat Impacts, relative values describing the co-occurrence of beats and syllables and (2) Onset+, absolute deviation of a Beat Impact from the syllable onset end. Subsequently, we calculate correlations between Beat Impacts/Onset+ values and relevant acoustic and structural parameters
(e.g. duration, F0, number of phones per syllable, etc). The main findings of the investigation of the local level concerns the relative timing between a musical beat and a co-produced syllable. This relationship shows the importance of automatically extracted p-centers as anchors between music and speech. The global level describes timing relationships between the beats/syllables with respect to various levels of rhythmical organization. In order to extract these levels from a musical beat sequence we use oscillator systems proposed by [1]. The findings show that these oscillator systems are able to detect rhythmical levels in the input beat trains extracted from the original instrumental music. The oscillators are even able to reproduce the structures of single instrumental tracks. This was evaluated by applying the correlation analysis used in the local level investigation. The results show clear cases of rhythmical entrainment between music and speech production in the case of rap singing. Furthermore we show how such a process can be modeled and reproduced in technical systems.

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Neural correlates of meter and rhyme in poetry

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Metered language can be found in virtually every human culture and in a wide variety of social contexts. Its salient feature is regular acoustic patterning superimposed on the 'normal' rhythmic patterns of language. The extra (poetic) effort required by this patterning appears to provide functional benefits, such as enhancing emotional content, synchronizing movements, and emotions in groups.

In the current fMRI investigation we addressed the question of how such patterning impacts emotional perception. We drew on the most common form of traditional German poetry, the German ballad stanza. This poetic structure involves stress-timed verse and rhyme. A corpus of 60 carefully selected stanzas were systematically manipulated in order to test the effect of regular vs. irregular meter and its consequences on emotional perception.

Results from this investigation reveal that next to neural correlates of beat (basal ganglia) and emotion perception (anterior cingulate cortex (ACC), orbito-frontal cortex (OFC)), a network involved in sustained attention is activated when listening to poems with coherent rhyme and metric structure. Poems without these structural anchor points result in activation of the bilateral superior temporal gyri (STG). The data clearly emphasize the emotional and attentional impact of rhythmic patterns in the perception of auditory art such as poetry.

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Hear it Low and Slow: Bidirectional Pitch Changes Differentially Influence the Perception of Interval Duration

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Rhythm and pitch perception have been behaviorally dissociated in neuropsychological populations and are generally thought to rely on separate neural substrates. The influence of temporal context on interval timing has been previously described in the literature, however, the influence of non-temporal cues, such as pitch on time perception has not been fully explored. We therefore investigated the influence of pitch on the perception of interval durations within the context of two different beat structures (300 ms and 600 ms). Participants listened to auditory sequences composed of six 50 ms isochronous tones of the same pitch. Two additional 50 ms tones at a higher, lower, or the same fundamental frequency as the previous six followed the isochronous series. To ensure that all final interval tones were easily distinguishable from the previous six, the harmonic structure of these two tones differed from the isochronous series. The final two tones demarcated a final interval that began on the established beat, but varied in duration (between 240-360 ms or 480-720 ms). Participants were asked to judge whether or not the final interval sounded like it was "speeding up" or "slowing down" relative to the preceding intervals. Analysis of the response classifications indicated that final intervals demarcated by higher pitched tones were underestimated in duration, while those demarcated by lower pitched tones were overestimated when compared to the perceived duration of final intervals demarcated by tones of the same fundamental frequency as the preceding isochronous series. Response time data showed an interaction between pitch and duration that supported the psychophysical data. Our findings suggest that interval timing can be influenced by non-temporal cues such as pitch. While rhythm and pitch perception may be processed separately, these results suggest that the neural substrates that mediate these processes may interact in a systematic way within cortico-striatal circuits subserving interval timing.

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A neurodynamic model of musical timing

Edward Large[1]

In rhythm perception the experience of periodicity, ie pulse, can arise even when no corresponding objective periodicity exists among the acoustic events that comprise the rhythm. One possible function of such a transformation is to enable complex attentional and behavioral coordination among individuals through perception of a common abstract temporal structure. Entrainment of neuronal oscillations to auditory stimuli has been observed in humans in the gamma, beta and delta frequency bands, and cortical entrainment has been directly implicated as a mechanism of attentional selection. Here, I adopt a neurodynamic approach to rhythm perception, and ask whether a model of neural resonance can account for key aspects of human rhythm perception. I begin with a model of oscillation in excitatory and inhibitory neural populations and derive a canonical model of neural oscillation. I stimulate neural oscillators with a variety of rhythms from simple isochronous sequences to syncopated rhythmic patterns, which contain no energy at the pulse frequency. I ask how well the behavior of the network matches human behavior, and compare the predictions of the nonlinear model with those of a linear filter based model. The neural model reproduces certain basic results associated with human pulse perception. In addition, I discuss several new predictions that have no correlate in music-theoretic models of pulse and meter.

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Timing in continuous drawing task: could it be more explicit?

Jacques Larue[1]

Timing in a continuous movement task is known to differ from the timing of discrete. Emergent timing found in continuous circle drawing could be due to the absence of explicit starting and ending points. What would happen if the continuous drawing task includes cues about position and timing? We tested 20 subjects performing continuous drawing of ellipses. They had to cross a given point on the ellipse at a regular pace. The task was performed without feedback or with enhanced feedbacks (beep sound when crossing, and tactile micro bump). Each feedback was tested under three timing paces (spontaneous, 35% faster and 35% slower). Synchronization and continuation paradigms were used. Results did not show any change in the shape of the ellipse, but as the pace increased, the long diameter and the surface area slightly increased. As expected, the pace affected also the timing error; however, coefficient of variation did not (mean = 6.5%). There was no change in error nor in variability across feedback conditions. Clock and motor variances were computed from detrended inter ellipse intervals (IEI); unfortunately, less than 25% of the trials respected the validity conditions of the Wing & Kristofferson method. Enhanced feedback clearly modified the drifting in IEI (as measured by the slope of the linear trend). During continuation, the no-feedback reduced the trend in IEI whereas both enhanced feedback increased the drift toward a slower pace. However, pacing was getting slower in continuation and, contrary to continuation, the IEI drifted downward when feedback was provided. Therefore, it appears that explicit timing feedback provided during continuous movement modifies the timing behavior. This change does not occur through modifications of the movement itself. Changes in drifting suggest either a modification of the internal clock reference or a change in the decay of the internal interval reference.

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Using changing anisochrony in a sensorimotor synchronisation paradigm to investigate error correction and long-term memory

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Sensorimotor synchronisation experiments largely use predictable sequences in order to test people's capabilities, and perturbations tend to be introduced in very controlled ways. In contrast, when people attempt to synchronise their movement with others, there is almost inevitably irregularity in the sequence, both intentionally, and due to imperfections in beat and meter production, even by musicians. As there has been much investigation into the ways in which error correction can occur, and recent interest in the possibility of long-term memory in sequences of tapping data (e.g. Delignières, Torre and Lemoine, 2009), the principles developed should be applicable to more ecologically valid examples of synchronisation, in which there is more variability within a sequence. The current study develops a paradigm introduced by Madison and Merker (2002) which used an unpredictably anisochronic auditory pulse sequence as a stimulus. Using this kind of sequence in a tapping experiment, and changing the level of anisochrony in the stimulus over time, encouraged dynamic changes in the error correction response by participants. All trials involved an underlying beat of 600ms, but each interonset interval was actually either shortened or lengthened. Throughout the trial, the amount of anisochrony changed and trials either became more isochronous or more anisochronous. Participants were not musically trained. The data were used to test how error correction and long term memory might operate in response to these dynamic changes, using a range of time series analysis techniques. Results suggest that using anisochronic sequences reduces autocorrelation in the intertap interval, but long-term memory is still a feature, both when synchronising with sequences that become more isochronic and those that become more anisochronic. Error correction in anisochronic conditions is less complete than under isochrony, and the preceding asynchrony is a fair predictor of the succeeding intertap interval. The importance of individual differences is emphasised.

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The Rhythm and Meter of Nursery Rhymes are Reflected in Patterns of Slow Amplitude Modulation (AM) in the Acoustic Signal

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Nursery rhymes are perfect metrical poems with a strong rhythmic beat. Meter is a hierarchically-organised construct emerging from the interaction of beat patterns on multiple time scales while rhythm is related to the regularity of beat intervals. Here we investigate the correlates of rhythm and meter in the acoustic signal of spoken nursery rhymes. We hypothesised that rhythm would be related to periodicity in slow amplitude modulations (AM) while meter would be related to patterns of co-modulation between AMs at different rates.

5 British-English speakers produced 27 nursery rhymes in a rhythmic or non-rhythmic (‚reporting') style. Speech samples were demodulated and their amplitude envelopes passed through a low frequency (<40 Hz) 5-channel modulation filterbank. Filtered modulators represent ‚beat patterns' in speech at different temporal rates (eg. syllable patterns at 4-7 Hz, stress patterns at 1-3 Hz). Modulator sets were analysed for periodicity using autocorrelation measures, and for patterns of co-modulation using phase-locking measures. Rhythmically-spoken rhymes were more periodic than ‚reported' rhymes for AMs between 1-7 Hz. Furthermore, rhythmically-spoken rhymes showed strong phase-locking between adjacent modulator harmonics. One modulation cycle at a given rate typically encompassed two cycles at the next rate. These occurred near the peak (loud) and trough (soft) of the slower cycle. This ‚strong-weak' pattern of interaction was repeated across several modulation rates resulting in a hierarchically-nested, fractal structure. Reported rhymes showed similar patterns of phase-locking, but with lower consistency.

The alternation of strong-weak elements in acoustic AMs is consistent with descriptions of the metrical structure of nursery rhymes (Gueron, 1974). The fractal structure also resonates well with hierarchical models of musical meter (eg. Lerdahl & Jackendoff, 1983). Co-modulation patterns in low AM frequencies may form the basis for our psychological perception of meter, while periodic regularity in AMs at syllable and stress rates may underlie speech ‚rhythmicity'.

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Mechanisms of interpersonal coordination in duet music performance

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Little research has examined how musicians achieve the precise temporal coordination that is required for ensemble music performance. The current study investigated two mechanisms that may underlie this coordination: co-representation, in which duet partners activate representations of each other's actions, and simulation, in which duet partners simulate the timing of each other's actions using their own motor systems. Pianists performed right-hand melodies along with simple or complex left-hand accompaniments produced by themselves (bimanual condition) or by another pianist (joint condition). Each pianist also performed the right-hand melodies without accompaniment (unimanual condition). The complexity of the left-hand accompaniment influenced the timing of the right-hand melody in the same way whether it was performed by the self (bimanual) or by the duet partner (joint), supporting the hypothesis that representations of partners' actions are activated during duet performance. Partners who were more similar in preferred unimanual performance rate were better synchronized and showed mutual adaptation to each other's timing during joint performance, supporting the hypothesis that co-performers who are more similar are better able to simulate each other's actions and thus better able to coordinate with each other. These results extend previous findings of co-representation and simulation to a task that requires precise temporal coordination of independent yet simultaneous actions.

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Effects of personality on synchronization to music

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Movement to music is ubiquitous. Listeners tend to employ foot-tapping and body-swaying movements to parse musical structure, and use different types of movements to embody different metrical levels of the music. Recently, personality has been shown to affect the type of movements people make. Here, we examine the effect of personality on the synchronization of such movements with the music. Thirty rhythmic music excerpts, each 30 s in length, representing six genres (pop, rock, latin, jazz, techno, and funk) were presented to 60 volunteers (43 female; mean age = 24; age SD = 3.3) individually. Participants were fitted with 28 reflective markers, and instructed to dance or move to each excerpt in a manner which felt natural. Movement was recorded using an eight-camera optical motion capture system (Qualisys Pro Reflex) at 120 Hz. Personality was assessed using the Big Five Inventory (BFI). For each excerpt, periodicity of seven body parts (neck, right shoulder, left hip, wrists, and ankles) was derived using autocorrelation, and synchronization error relative to four metrical levels (half, one, two, and four times the beat period) calculated. Subsequent analyses were based on the beat level with the smallest difference. Positive relationships between high vs. low personality scores and synchronization accuracy (lower synchronization error) were identified for Openness (ankles, wrists, shoulder, and neck), Conscientiousness (ankles, shoulder, and neck), and Agreeableness (ankles and right wrist). Negative relationships (higher synchronization error) were observed for Extraversion (left wrist) and Neuroticism (ankles). The clearest pattern of results was observed for Openness, with body parts being synchronized along multiple planes of movement. We conclude that personality not only influences the types of movements people make while listening to music, but also the synchronization of these movements to the music.

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An auditory illusion of infinite tempo change and some of its applications

Guy Madison[1]

Sequences of identical sounds with isochronous temporal spacing are common stimuli in psychological research. It is a striking fact, however, that such sequences are unusual in music, the cultural domain to which they are chiefly attributed. Most music can be characterized by a multi-level temporal hierarchy, as reflected by duration values dominated by integer relations of two or three. Here, I demonstrate an illusion of infinite tempo change built on the interchangeability of levels in a multi-level temporal pattern (http://dx.plos.org/10.1371/journal.pone.0008151), in the spirit of Shepard's circularity in pitch and the work of Risset. The behaviour of human participants when synchronizing with this illusion is described.

As one example of an application of the multi-level pattern (MLP), I present results of a study in which people were asked to synchronise with a MLP that did not change in tempo. The MLP was repeatedly presented with different base rate, and the dependent variable was which level they choose to synchronise with. This re-addresses the old question in rhythm research of what constitutes the most natural or preferred tempo. Asking people to produce the rate that seems most comfortable is called personal or spontaneous tempo, while preferred tempo refers to how pleasing or comfortable are different rates to listen to. The participants' inter onset interval grand mean was around 750 ms, which is longer than in previous studies of personal or spontaneous tempo. Individual differences were also apparent, and all of this is discussed with respect to our perception of complex temporal patterns.

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The role of multiple rhythmical levels in the perception of music: Judgments of speed increase with event density

Guy Madison[1], Johan Paulin[1]

There is an apparent contradiction between the narrow range of tempi optimal for perceptual judgment and motor synchronisation and the wide range of beat tempi found in real music. The relation between listeners' perception of speed and beat tempo was therefore investigated, both for real music excerpts (ME) and metronome sequences. Tempi ranged from 42 to 200 beats per minute (BPM), and some excerpts were further tempo manipulated in four levels from ±5 to ±20%. Regression analyses showed that speed was a shallower function of original tempo for fast (> 150 BPM) and slow (< 95 BPM) MEs than for MEs with intermediate tempi, describing a non-linear, sigmoid function. Manipulated tempo had twice as large an effect on speed as had original tempo. In contrast, speed was an almost linear function of tempo for metronome sequences. Taken together, these results show that the non-linearity stems from properties of the musical signal, rather than being a subjective perceptual effect. They indicate an inverse relation between tempo and relative event density in real music, and demonstrate that the perception of periodic signals is affected not only by the beat level, but also by faster and slower levels.

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Neurophysiology of temporal processing during a synchronization-continuation tapping task

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Behavioral timing is a supramodal variable essential in coordinate motor control, commonly exemplified in music and skilled motor performance. How do groups of neurons process temporal information to coordinate timed actions with a predictable external event is still unclear. Two monkeys were trained in a synchronization (S)-continuation (C) tapping paradigm, in which auditory cues were presented to construct the periodic target interval ranging from 0.45 to 1 second. Initially, animals synchronized their tapping movements with a sensory cue by tapping on a push-button, followed by self-pacing of the target interval when the metronome was switched-off. We recorded the single-cell activity of 1500 neurons from the macaque medial premotor cortex (MPC) during the task performance. The main findings of this study are:

1) Many MPC neurons showed ramping activity whose duration increased and slope decreased as a function of the duration of the produced interval, reaching their activity peak at similar times with respect to button press. These cells could be the neural representation of time remaining during the task. We propose a cell population model, where the population signal triggers a tapping movement when it reaches a particular magnitude at a specific time remaining to button press.

2) Another population of cells showed a linear decrease in activity when aligned to previous tapping movement. This could be a neural correlate of elapsed time from a movement, where the actual level of activity can be associated with subjective time.

These results suggest that distinct populations of cells in the MPC can encode elapsed and remaining time during a multiple interval production task that has a cyclic component and requires the temporal control of behavior cued by auditory stimuli followed by a phase of tapping that is internally timed.

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Interactive rhythmic auditory stimulation reinstates natural 1/f timing in gait of Parkinson's patients

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Parkinson's disease (PD) and basal ganglia dysfunction impair movement timing, which leads to gait instability and falls. Parkinsonian gait consists of random, disconnected stride times—rather than the 1/f structure observed in healthy gait—and this randomness of stride times (low fractal scaling) is a strong predictor of falling. Walking with fixed-tempo Rhythmic Auditory Stimulation (RAS) can improve many aspects of gait timing; however, it lowers fractal scaling (away from healthy 1/f structure) and requires attention. Here we show that interactive rhythmic auditory stimulation effortlessly reestablishes healthy gait dynamics in PD patients. In the experiment, PD patients and healthy participants walked with a) no auditory stimulation, b) fixed-tempo RAS, and c) interactive rhythmic auditory stimulation. The interactive system used foot sensors and nonlinear oscillators to track and mutually entrain with the human's step timing. Patients effortlessly synchronized with the interactive system, their fractal scaling returned to levels of healthy participants, and their gait felt more stable to them. Patients and healthy participants rarely synchronized with fixed-tempo RAS, and when they did synchronize their fractal scaling declined from healthy 1/f levels. Five minutes after removing the interactive rhythmic stimulation, the PD patients' gait retained high fractal scaling, indicating that the interaction stabilized the internal rhythm generating system and reintegrated timing networks. The experiment demonstrates that complex interaction is important in the (re)emergence of 1/f structure in human behavior and that interactive rhythmic auditory stimulation is a promising therapeutic tool for improving gait of PD patients.

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Conveying syncopation in music performance

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Syncopation occurs when the rhythmic foreground does not coincide with the regular metric framework. It is a common phenomenon in different musical styles and playing syncopated rhythms is a standard technique for most musicians. Research on syncopation has focuses on timing in simple rhythmic sequences. In this paper we want to investigate how musicians convey syncopation in performance. Starting-point was the method developed by Sloboda (1985), who let musicians perform the same piece of music, changing only the metric structure. In this study, three short rhythms were used in a metrically regular and a syncopated version, using three different melodies, thus creating 18 musical phrases. 20 professional musicians (5 violinists, 5 pianists, 5 guitarists and 5 clarinetists) with a career as a performer played these 18 phrases in four different orders. They were asked explicitly to communicate the rhythmic character as clearly as possible. Besides audio and video-recordings, three accelerometers were attached to the head and the arms of the performers. Although differences between rhythmic patterns and performers exist, there are some more general results: syncopated versions were played faster, louder and with less agogic accents, and most performers moved more, especially with the head. A selection of the video and audio recordings is now being presented to a group of subjects who are asked to label them as 'regular' or 'syncopated'. This will show us if performers are successful in conveying syncopated rhythms and if listeners can determine syncopation based on audio alone, or need additional video information to successfully determine the rhythmic character.

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Tagging the neuronal entrainment to beat and meter with steady-state evoked potentials.

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Feeling the beat and meter is fundamental to the experience of music. However, how these periodicities are extracted and represented in the brain remains largely unknown. Here, we test whether this function emerges from the entrainment of neurons resonating at the frequency of beat and meter. We recorded the electroencephalogram while participants listened to a musical beat and imagined a binary or a ternary meter of this beat (i.e. a march or a waltz). We found that the beat elicits a sustained periodic EEG response tuned to the beat frequency. Most importantly, meter imagery elicits an additional frequency tuned to the corresponding metric interpretation of this beat. These results provide compelling evidence that the neural entrainment to beat and meter can be captured directly in the electroencephalogram. More generally, our results suggest that music constitutes a unique context to explore entrainment phenomena in dynamic cognitive processing at the level of neural networks.

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The effect of synchronous reading on speech rhythm

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We apply the coupled oscillator model (COM, cf. O'Dell & Nieminen 2009) of speech rhythm and analysis techniques developed in O'Dell et al. (2007; 2008) to a database of synchronously read Finnish speech (O'Dell et al. 2010; see Cummins 2009 for an overview of the synchronous speech paradigm). Our data includes speakers reading the same text by themselves as well as synchronously
in pairs. By analyzing both readings it is possible to assess the effects of synchronizing on the rhythm. The COM itself is based on synchronization of component rhythms and is thus well suited to modeling such effects. Our previous work has indicated that Finnish has a strong phrasal stress rhythm combined with a strong mora rhythm (O'Dell et al. 2007:1203). On the other hand, while synchronous speech is known to reduce timing variability (Cummins 2004), our previous research has indicated that speakers reading synchronously
synchronize primarily at the phrasal level, not at a finer grained level (O'Dell et al. 2010). Results of the analysis will help with our current work to accommodate pausing behavior and incorporate interspeaker coupling into the COM.

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The role of conscious and automatic processes in temporal prediction during sensorimotor synchronization

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Musical ensemble performance requires precise action coordination. To play in synchrony, musicians presumably anticipate the sounds that will be produced by their co performers and coordinate their own anticipated actions with these predictions. Our previous studies revealed individual differences in musicians' temporal prediction abilities during on beat finger tapping to a tempo changing pacing signal. An ongoing study examines the degree of cognitive control that is required for generating such (more or less accurate) temporal predictions. Cognitive load was varied by means of a visual n back working memory task (comprising 3 levels of difficulty: observation only, 1 back and 2 back object comparisons) that was administered while participants tapped to a tempo changing pacing signal. Results indicate that the degree to which individuals predict ongoing tempo changes decreases with increasing working memory demands. We are currently administering an additional set of finger tapping tasks to investigate the relationship between automatic (phase) vs. conscious (period) error correction and temporal prediction mechanisms. We hypothesize that individual differences in sensorimotor synchronization performance depend more strongly on temporal predictions mediated by conscious top down processes than on automatic, bottom up processes.

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How do we measure rhythm? An explanatory approach to speech timing.

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Speech timing constitutes one main pillar supporting linguistic rhythm. In recent years, it has been generally agreed that perceived differences between languages like French ('syllable-timed') and English ('stress-timed') can be captured by 'rhythm metrics', or acoustic measures of durational variability among consonantal vs. vocalic portions of speech signals. Such metrics are designed to reflect the complexity of syllable structure and the degree of vowel reduction (Ramus, Nespor & Mehler 1999). However, this approach has several limitations (e.g. Arvaniti 2009; Barry, Andreeva & Koreman 2009). Rhythm metrics are neither exploratory nor explanatory; they assume apriori a straight-forward relationship between perceived rhythm class, segmental distribution and duration. And yet duration is a cumulative exponent of many layers of the prosodic hierarchy; and durational variation cannot be attributed only to the phonetic realisation of the underlying phonology and phonotactics.

In our study, we took an exploratory approach to speech timing and examined the effect of three macro-rhythmic factors (stress, accentuation, and phrasing) on syllable durations in read stories and nursery rhymes from two accents of British English from Yorkshire: (1) a clearly 'stress-timed' variety spoken by monolingual speakers from Leeds, and (2) a variety spoken by Panjabi-English bilinguals from Bradford which has been claimed to sound more syllable-timed (Heselwood & McCrystal 2000). Preliminary results from four speakers of each dialect show that Leeds and Bradford differ as expected on the VarcoS metric, a measure of variability in syllable duration. The difference in score, although very subtle (0.51 vs. 0.48), seems to be mainly triggered by phrasing, since phrase-initial shortening and phrase-final lengthening are less pronounced in Bradford. However, we also found less prominence-related lengthening (due to stress and accentuation) in Leeds. These results supportthe assumption that the 'rhythm space' is multi-dimensional, allowing diverging rhythms to co-exist in the same language or variety (Nolan & Asu 2009). Our study contributes to the understanding of the 'rhythm space' beyond phonotactics and vowel reduction.

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Anticipatory Phase Correction in Sensorimotor Synchronization

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Studies of phase correction in sensorimotor synchronization often use a perturbation method. The perturbations typically are unpredictable with regard to direction, magnitude, and position. If participants knew any or all of these parameters in advance, would they be able to anticipate and adjust more quickly to perturbations?

In Experiment 1, we asked participants to tap in synchrony with short isochronous tone sequences (inter-onset interval [IOI] of 500 ms) containing a single phase shift (PS) of -100, -40, 40, or 100 ms. In four conditions, we provided advance information about (A) PS direction (an arrow), (B) PS position (a pitch change in the preceding tone), (C) both, or (D) neither. Results showed that the information in conditions A and B had little effect, but in condition C participants shifted their critical tap in anticipation of the PS, though only by about ±40 ms on average. The phase correction response to the residual PS was enhanced compared to condition D.

In Experiment 2, we investigated how quickly and accurately participants can shift a tap in anticipation of a PS about which they are given complete advance information. A visual analog display (a Max slider) indicated PS direction and magnitude either at the time of the tone immediately preceding the PS ("late") or one position earlier ("early"). Each tone sequence had one of five tempi (IOIs of 400 to 1200 ms) and contained 10 PSs ranging in magnitude from -50% to 50% of the IOI, randomly ordered and spaced apart. Results showed that anticipatory phase correction increased steadily with IOI in the "late" condition, reaching the level of the "early" condition only at the longest IOIs. This suggests that up to 1 s is needed to prepare an accurate anticipatory shift of a tap. Anticipation was generally conservative (not more than 80% of the PS on average) and larger for positive PSs (delays) at short IOIs but larger for negative PSs (advances) at long IOIs. The phase correction response to the residual PS was somewhat stronger in the "late" than in the "early" condition and similar to the response to unanticipated PSs in another study, except for some enhancement at the fastest tempo.

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Evidence of metric and syntactic violation detection among Spanish late learners of German: An ERP study

Maria Paula Roncaglia[1], Maren Schmidt-Kassow[2] and Sonja A. Kotz[1]

During the first year of live, infants encode rhythmic properties, such as stress pattern that are relevant for speech segmentation, becoming insensitive to rhythmic properties of other languages (Juczyk, Cutler & Redanz, 1993). Dupoux et al (1997) report stress "deafness" among French native speakers for being stress variation non-contrastive in this language. Schmidt-Kassow et al. (2011) find ERP evidence for such "stress deafness" among proficient French late learners of German. Differently from French, lexical and contrastive stress are present in Spanish. Therefore, Spanish late learners of German should be able to detect metric violations. In the current experiment, subjects were presented with auditory sentences, containing syntactic, or metric violation or both (syntactic and metric). Behavioral and ERP results revealed that Spanish later learners of German can detect metric and syntactic violations, but in a different fashion than native speakers. This may be due to the rhythmic differences between their L1 (Spanish) and L2 (German).

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Synchronizing with regular and with aksak rhythms

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Eight professional and amateur musicians were studied in a synchronization-continuation task with repeating regular (2:1, 3:1, 3:2:1) and aksak rhythms (3:2, 3:2:2, 3:3:2) at two tempi. Rhythms were presented as sequences of high tones ("beats"), the underlying meter by low tones ("pulses"). After four initial measures of synchronization, participants continued for another eight measures, with either the beats only, the off-beat pulses only, or all pulses present, or fully self-paced. We present the results of fitting alternative extensions of the two-level synchronization model (Vorberg & Schulze, 2002) to the data.

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(Sensori-)motor synchronization and its influence on the auditory processing of deviance

Michael Schwartze[1], Maren Schmidt-Kassow[2] and Sonja A. Kotz[1]

Continuous adaptation of behavior to an ever-changing environment is an essential characteristic of life. In order to be efficient, adaptation requires an individual not only to react to changes, but also to predict future changes or events, and to adjust behavior accordingly. The key to prediction is formal and temporal regularity, i.e. some recurring stable relation that allows inferring the nature and the future course of events. While the perception of such regularity depends on the ability to evaluate formal and temporal features of events, its behavioral implementation requires also precise motor planning and production. However, when these mechanisms converge, they offer a powerful aid to optimize processing in both, perception and production. In the current study we used behavioral measures and event-related potentials (ERP) of the Encephalogram (EEG), namely N2b and P3a, to compare sensory and sensorimotor synchronization and their influence on another cognitive process, i.e. the processing of an acoustically deviant event. During EEG recording, participants either listened attentively or listened attentively and synchronized their finger tapping to 200 sequences of 7-10 sinusoidal tones (600 Hz) with a base tempo of 600 ms. The last three tones of a sequence contained either a change in pitch (660 Hz; 20 %), tempo (-75 ms; 20 %), pitch and tempo (660 Hz; - 75 ms; 20 %), or no change (40 %). Results suggest a global enhancement for deviance processing in the sensorimotor as compared to the sensory pitch change condition, while precise tapping in a subgroup of participants leads to enhanced deviance processing, i.e. larger N2b and P3a amplitudes, in the sensorimotor tempo change as well as the combined tempo and pitch change conditions. These findings suggest that precise combined sensory and motor synchronization bears the potential to optimize attentional deviance processing.

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Effect of beat isochrony and motor entrainment on music performance in a child drummer prodigy

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A great deal of research has been devoted to synchronization of perception and action (mostly via the finger tapping task), and more generally to entrainment, in average musicians and non-musicians. Much less is known about the effects of entrainment on music performance (not just tapping) in individuals exhibiting outstanding rhythmical abilities (e.g., exceptional drummers), and on movement kinematics. The aim of this study is to examine the effect of beat isochrony and motor entrainment on the performance of a child drummer prodigy (IF). IF is a 7-year-old drummer who revealed at a young age (from age 3-4) very precocious and outstanding musical abilities, and who exhibits exceptional accuracy in sensorimotor synchronization tasks. In the present study we examined IF's music performance when temporal regularity of the underlying beat was progressively disrupted. IF and a control group (i.e., children from music schools with 1-to-2.5 years of percussion training) were tested in a motion capture experiment. Participants imitated a short 6-note isochronous metrical pattern (Strong-weak-weak-Strong-weak-weak) under four conditions. In the first condition the pattern was repeated ten times following a metronome. In the second condition, the pattern was repeated but with a break in between repetitions, which however did not affect beat isochrony as conveyed by the metronome. In the third condition, similar breaks were introduced, this time disrupting beat isochrony. Finally, in the fourth condition break durations were random. Preliminary results show that IF exhibited higher temporal accuracy than controls in all conditions but less visible in conditions with reduced or absent beat isochrony; moreover overall differences in movement kinematics, as revealed with Functional Data Analysis (e.g., in terms of movement amplitude, and anticipation times) between IF and controls are also observed. These findings are discussed in the context of models of time processing and movement kinematics in music performance.

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Hearing the speed of the moving dots: visual motion biases non-spatial auditory tempo perception

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Rhythm is commonly an auditory experience that entails both auditory and motor processes, and the percept typically involves an audio-motor representation. In this study we tested the hypothesis that the visual motor information such as embedded in a coherent motion flow – presumably by means of visuo-motor representation – can interact with the motor-related property in auditory rhythm, such as the tempo. In two experiments, we employed an auditory tempo judgement task where participants listened to a standard auditory sequence while concurrently watching visual stimuli of different motion information, after which they judged the tempo of a comparison sequence related to the standard. In Experiment 1, we found that the same auditory tempo was perceived as faster when it was accompanied by accelerating visual motion than by non-motion luminance change. In Experiment 2, we compared the perceived auditory tempo amongst three visual motion conditions: increase in speed, decrease in speed, and no speed change, and found the corresponding bias in auditory tempo: faster than it was, slower than it was, and the same. The results indicated that between a visual spatial and a auditory temporal stimulation, the embedded motor representations from each can interact across modalities, leading to a spatial-to-temporal bias. This suggests that the perceptual process of auditory rhythm can incorporate relevant motor information from various sensory inputs to form a coherent experience.

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Processing and representing temporal patterns in the brain: A classifier and scaling analysis

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Two adjacent empty time intervals t1 and t2 marked by three successive tone bursts are often perceived to have equal duration even if they are physically unequal within the range $-80 \leq t1\text{-}t2 \leq 50$ [ms]. This illusory phenomenon is called auditory temporal assimilation (e.g. Nakajima, ten Hoopen, & van der Wilk, 1991; Miyauchi & Nakajima, 2005). In order to clarify underlying mechanisms, Mitsudo et al. (2009) conducted an event-related potential (ERP) study. We reanalyzed their data, and calculated informational separation in the ERP waveforms between two response conditions: In the J condition, the participants made judgments about the intervals; in the NJ condition, the participants only listened to the temporal patterns without judgments. The separation increased monotonously with the progress of time until the whole temporal pattern was presented. This represented temporal pattern processing that led to the slow negative ERP component (SNCt), which Mitsudo et al. (2009) had found to be associated with temporal judgments. The SNCt had been observed in a comparison between the waveforms for the J and the NJ condition after presentation of the whole temporal pattern, with the larger amplitude for the temporal patterns that were mostly perceived as consisting of unequal intervals (the UE patterns) than for the temporal patterns that were mostly perceived as consisting of equal intervals (the E patterns). We applied multidimensional scaling to the Euclidean distances between correlation matrices of the ERP waveforms. A local maximum of distance was found between the E- and the UE-pattern category, within 100 ms after presentation of the whole temporal pattern, as a reminiscence of the SNCt. Interestingly, this was the case not only in the J but also in the NJ condition. Results in the NJ condition thus indicated a possibility to relate brain activities, without observable responses, directly to perceptual categories in mind.

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Top-down anticipatory effects on MMN highlight prediction-based modification of initially stimulus-driven rhythmical pattern perception

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A repeated ordered sequence of sounds is perceived as a succession of individual sounds if the Inter Stimulus Interval (ISI) is long enough to prevent perceptual grouping and subjects are not informed about the sequential pattern (Non informed condition). The occurrence of a deviant sound elicits the Mismatch Negativity (MMN) event-related component indexing regularity-violation detection (Schröger, 2007). Congruent top-down information can modify stimulus-driven information. When subjects entertain explicit information on the incoming sound pattern (Informed condition), MMN is greatly reduced in amplitude, suggesting that perception of incoming patterns is fully predictable and thus no deviance is detected (Sussman et al., 2002). However, when a strongly rhythmical structure becomes perceptually dominant (ISI =) it is thought to override any predictability cue provided by top-down information (Sussman and Gumenyuk, 2005). We tested this hypothesis using a continuously repeating, ordered sequence of five 50-ms sine tones, the first four being repetitions of a standard tone (440 Hz), and the last a frequency deviant tone (494 Hz). Sequences were played at two different blocked ISI conditions, 700 ms and 200 ms. The Electroencephalogram (EEG) of 19 participants was recorded while they were engaged in detecting rare (5%) lower frequency target tones (349 Hz). 700-ms blocks always preceded 200-ms blocks, and the Informed condition always followed the Non-Informed condition. Results show a significant reduction in the amplitude of the MMN component and NO-GO P3 wave in the 700-ms ISI in the Informed condition. As for the 200-ms ISI, no differences in MMN were found between Informed and Non-informed conditions at frontal sites. A significant anticipatory effect on the latency of the MMN in the Informed condition only was found for electrodes at temporo-parietal sites, suggesting that top-down predictability cues are not fully overridden by stimulus-driven rhythmical pattern perception.

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Distinct neural substrates of duration-based and beat-based auditory timing

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Research on interval timing strongly implicates the cerebellum and the basal ganglia as part of the timing network of the brain.

Here we tested the hypothesis that the brain uses differential timing mechanisms and networks – specifically that the cerebellum subserves the perception of the absolute duration of time intervals whilst the basal ganglia mediate perception of time intervals relative to a regular beat.

In a functional magnetic resonance imaging experiment, we asked human subjects to judge the difference in duration of two successive time intervals as a function of the preceding context of an irregular sequence of clicks (where the task relies on encoding the absolute duration of time intervals), or a regular sequence of clicks (where the regular beat provides an extra cue for relative timing).

We found significant activations in an olivocerebellar network comprising the inferior olive, vermis and deep cerebellar nuclei including the dentate nucleus during absolute, duration-based timing and a striato-thalamocortical network comprising the putamen, caudate nucleus, thalamus, supplementary motor area, pre-motor cortex and dorsolateral prefrontal cortex during relative, beat-based timing.

Our results support two distinct timing mechanisms and underlying subsystems: firstly, a network comprising the inferior olive and the cerebellum that acts as a precision clock to mediate absolute, duration-based timing and secondly, a distinct network for relative, beat-based timing incorporating a striato-thalamo-cortical network.

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Multiple-look effects on temporal discrimination within sound sequences

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AIM:
To deconfound the design of the seminal study by Drake & Botte (1993) in which they studied the multiple-look notion as regards temporal discrimination between sound sequences [the multiple-look notion holds that the DL decreases with multiple observations]. Their listeners had to discriminate between a standard (S) containing 1, 2, 4, or 6 isochronous time intervals and a comparison (C) also containing 1, 2, 4, or 6 isochronous time intervals. The S-C pairings were 1-1, 2-2, 4-4, and 6-6 intervals, implying a complete confounding of S and C.

METHOD:
In Experiments 1 and 2 we partly deconfounded Drake & Botte's design. There were 9 isochronous intervals, either before or after the tempo-change in the total sequence, and the number of intervals after or before the tempo-change increased from 1 to 9. The DLs for tempo-discrimination in the sequence were established by the method of constant stimuli and an interleaved staircase method. In Experiment 3 we completely deconfounded D&B's design: The number of intervals before and after the tempo-change varied between 1 and 5, and for all 25 combinations, the DLs were measured. The base IOIs varied between 100, 200, 400 and 800 msec (Experiment 1) and 200 and 400 msec (Experiments 2 and 3).

RESULTS and DISCUSSION:
The DLs decreased with interval accretion, both before and after the tempo-change, that is, multiple-look effects were observed. The effect of interval accretion before the tempo-change was twice as big as that after the tempo-change. There was a clear diminishing returns relation between the DL and interval accretion that could be described by a reciprocal function (DL = a + b/N msec). Our reciprocal diminishing returns model gives a much better fit to D&B's 1993-data, than their own multiple-look model did. We also discuss McAuley and Miller's (2005, 2007) "generalized multiple-look model".

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Implicit Learning of Between-Group IOIs in a Complex Temporal Structure

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Implicit learning (IL) occurs without awareness and intention and has been investigated using the Serial Reaction Time Task (SRTT). Despite reaction times (RTs) decreasing with exposure to a repeating sequence and increasing with the introduction of a new sequence, participants are often unable to report the learned structure. Our present study used an auditory SRTT to investigate IL of temporal structures. Participants discriminated syllables (Pa, Ta, Ka) presented in a pseudo-random order. During exposure, the presentation of syllables followed one of two repeating sequences of inter-onset intervals (IOIs). The alternate sequence was presented in a test block followed by a final exposure block. The temporal structures were weakly metrical, had identical figural groupings but differed in the duration of the between-group IOIs. As hypothesized, RTs tended to decrease with exposure. Moreover, RTs to syllables following between-group IOIs increased significantly (relative to the mean of adjacent exposure blocks) when shortened or lengthened in the test block. However, this finding was observed only for the group exposed to one of the temporal structures. In post-test assessments of explicit knowledge, participants performed short SRTTs with temporal structures the same (old) or different (new) from the experimental phase. Familiarity ratings were also given. As hypothesized, for the group that demonstrated learning, RTs in the post-test SRTTs were faster to syllables following between-group IOIs in the old compared to new temporal structures. There were no differences in familiarity ratings. In summary, exposure to one of the weakly metrical sequences elicited IL of between-group IOIs. Analyses (e.g. Pressing 1998; Shmulevich & Povel, 2000) of the unlearned structure indicated it was more syncopated and metrically ambiguous than the learned structure. This ambiguity may be an important consideration when investigating IL of temporal structure. Nonetheless, the findings suggest that between-group IOIs can be implicitly learned via exposure to a temporal structure.

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Effect of pattern complexity and expertise on movement kinematics during perception and reproduction of auditory rhythms

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The role of body movement in music-related activities has received increasing attention in recent years (e.g., Eerola, Luck & Toiviainen, 2006; Luck & Toiviainen, 2006; Palmer & Dalla Bella, 2004; Wanderley, Vines, Middleton, McKay & Hatch, 2005). Here, we examine the role of body movement in the perception and reproduction of rhythmic patterns, focusing in particular on the influence of rhythmic complexity and expertise on movement kinematics. Ten participants (4 skilled musicians and 6 non-musicians) listened to and reproduced 35 auditory patterns by clapping their hands. Rhythmic complexity of the patterns was computed using 5 indices: subjective evaluation, and Cscore and PSmeasure calculated on both eight- and quarter-note levels (Povel & Schmulevic, 2000). Full-body movement was recorded using an eight-camera motion capture system (Qualisys Pro Reflex) at 120 Hz, the data from which two kinematic measures were extracted: standard deviation of instantaneous speed, and total distance travelled by selected body parts. Additionally, participants' performance was evaluated qualitatively by the first author, and against the baseline of their spontaneous tempo. We identified systematic relationships between rhythmic complexity and the spatiotemporal characteristics of body movement during both perception and reproduction. Musicians, for example, tended to move less when listening to more complex rhythms prior to reproduction. Moreover, participants with a faster spontaneous tempo moved less in general compared to those with a slower spontaneous tempo. We conclude that bodily representation of the beat is tied to the rhythmic complexity of the pattern presented.

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"Beating together": Evidence that entrainment and affiliation mutually affect each other

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This study follows up on an earlier study (Turgeon and Fry, RPPW12) suggesting that not only does being together in time (entrainment) promote a sense of belonging together (affiliation), but also affiliation promotes entrainment (e.g., friends have lower synchronization errors when tapping a rhythm than non friends). Using a more controlled set up, eliminating visually mediated social cues, synchronization performance is assessed under different social-priming contexts. Experiment 1 involves really interactive conditions, that is, pairs of non-musician participants (friends or non-friends) that synchronize and continue either the same rhythm (in phase or out-of-phase) or different rhythms (i.e., polyrhythm; common 3.6-s cycle in phase or out-of-phase). The rhythms can be slow triplets (450,450,900 ms) or fast triplets (300,300,600 ms). All sounds are heard over headphones. The two partners initially synchronize to different pre-identified sounds (e.g., guitar vs. drum); in the continuing period they hear the sounds from the tap of their partner instead of their own. It is expected that friends will entrain more with each other than non-friends. The produced tap-time series then serve as pacing stimuli for the three conditions of Experiment 2, in which the same pre-recorded sounds are presented to one participant in an isolated sound booth. In the virtually interactive condition, the participant is told that the sounds are produced in real time by someone (a confederate) in another sound booth. In the non-interactive with agency condition, the participant is told that the sounds are pre-recorded and were produced by another participant (i.e., veridical situation). Finally, in the non-interactive without agency condition, the participant is told that the sounds originate from a computer simulation of human performance. Currently ongoing testing will answer whether a participant's entrainment with the pacing sequence is modulated by the perceived interactive context and/or agency of the sound source.

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Rhythm and Meter as Compositional 'Footprints' in 19th Century Art Songs

Leigh Van Handel[1]

This study extends prior research on the influence of linguistic rhythm on musical rhythm to 19th-century French and German art songs. A measurement of rhythmic variability, the nPVI, or normalized Pairwise Variability Index, has been used to demonstrate differences in the amount of rhythmic variability used in music. These differences may be attributable to characteristics of the spoken language, as hypothesized in a series of articles by Patel and Daniele and Huron and Ollen, who studied cross-language differences in rhythmic variability.

Results indicate a modification of the nPVI, called the pnPVI (for phrase-normalized Pairwise Variability Index) may be of use in studying individual compositional style even when a significant correlation with spoken language characteristics is not present in the repertoire. By modifying and focusing the results of the nPVI, and studying the relationship between rhythmic variability and notated meter, it is possible to determine musically meaningful information about individual composer's rhythmic characteristics.

When the pnPVI is calculated for metrical categories (simple and compound) or metrical types (simple duple, simple triple, etc.) the results highlight important cross-language differences that are not visible in a simple cross-language study, as well as provide insight into an individual composer's style of composition. The pnPVI measurement provides a quantitative measurement of an aspect of compositional style that has received little attention yet reveals significant differences among and across composers. The results of this study illustrate the use of the pnPVI measurement of rhythmic variability as an important music analysis tool that may be able to bring us closer to understanding the role of rhythmic variability in compositional style.

[1] Michigan State University, East Lansing, Michigan, USA

The influence of environment and music on walking speed and step tempo of pedestrians

Leon van Noorden[1], Marek Frank[2]

Walking speed depends on many factors, such as body size, fitness, age, culture, time pressure, activity and environment. However, under normal circumstances the step tempo is rather constant and close to 2 Hz. In this experiment the focus is on the influence of the visual and aural environments, such as be can be found in busy or quiet streets or park-like environments and the presence or absence of music of a Walkman. To this end students walked twice a 2 km long street circuit in the town of Hradec Králove in the Czech Republic, once with a Walkman and once without. Two three-day sessions were run with slight variations in spring and fall of 2010 with 62 and 75 subjects respectively. For capturing the environment and the behavior of the subjects, they walked with a very small video camera attached to a belt around their middle, looking forward. The camera was equipped with a fish-eye lens that could capture the environment in front of the subject and the feet, the arms (and often the nose) of the subject. We are able to extract pixels from each frame to construct a time-to-x image in which the placement of the feet in space and time is visible. From the movement of the camera the step tempo can be determined. Preliminary results of the first session show that there are systematic influences of the different environmental sections and interactions with the music/non music factor. The most remarkable result of the first session was that only one of the 60 odd subjects spontaneously walked in sync with the music. To investigate this further in the secondsession we presented music with a tempo even closer to the individual's spontaneous walking tempo without music. The results of this experiment will be presented at the conference.

[1] UNESCOG and IPEM, Belgium

[2] University of Hradec Králové, Hradec Králové, Czech Republic

Neuroelectric correlates of the P-centre

Rudi Villing[1]

Although the P-centre has often been measured and investigated using behavioural methods, none of the currently known methods can objectively measure the absolute P-centre (the true moment at which the event perceptually occurs) directly. A neural correlate, in contrast, would provide an objective means of measuring the P-centre and might even allow the moment of P-centre perception to be identified. A neural correlate might also provide insight into the mechanisms underlying P-centre production, thus informing any future P-centre model development. The auditory evoked potentials (AEPs) in response to P-centre stimuli were measured over the course of two EEG experiments. The results showed that the phase delay of lowest frequency AEP sub-bands predicts the variation between P-centres relatively well despite no single feature exhibiting a systematic relationship with the stimulus P-centres. Explanations of the results to date and ideas for future work will be discussed.

[1] NUI Maynooth, Co. Kildare, Ireland

A more realistic two-Level timing model with reafferent feedback loop

Dirk Vorberg[1]

The two-level framework introduced by Wing and Kristofferson (1973) explains what limits temporal precision in isochronous tapping, and offers a decomposition of the observed timing variability into central and peripheral sources. Its simplicity notwithstanding, the model has successfully passed numerous empirical tests, and serves as the basic building block in more complex models for rhythmic, bimanual, or synchronized tapping. Tests of the model's open-loop assumption, however (e.g., Drewing, 2006), suggest a reinterpretation in which the central timer, rather than initiating movements, sets up temporal goal points for anticipated action-effects. In the revised model, movements are triggered with variable delay from goal points, with delay period continuously adjusted for the asynchrony of the experienced action effect from its goal point. The revised model dynamically adapts to feedback perturbations, while at steady-state, its behavior closely mimics that of the original two-level timing model. Asymptotic predictions are now available in closed form, which permits estimating the model parameters.

[1] Westfälische Wilhelms-Universität, Münster, Germany

Ensemble timing in string quartet performance

Alan M Wing[1], Satoshi Endo[1], Adrian Bradbury[2] and Dirk Vorberg[3]

The high quality of synchronisation in music ensemble performance suggests that players actively respond to and correct asynchronies that arise from their fellow players' tempo fluctuations. A leading classical string quartet performed short extracts from Joseph Haydn Opp 74 and 77 with intentional, but unrehearsed, expressive variations in timing. Time series analysis, based on first-order, linear phase correction, revealed that the degree of temporal adjustment within the various duo permutations in the quartet differed from pair to pair. Contrasting patterns of timing corrections, between first and second violins, on the one hand, and viola and cello, on the other, are consistent with roles commonly assigned to different instruments in chamber music ensembles. Time series analysis offers a promising method for objectively characterising timing in music ensemble.

[1] SyMoN Lab, School of Psychology, University of Birmingham, Birmingham, UK

[2] Royal Academy of Music, University of London, London, UK

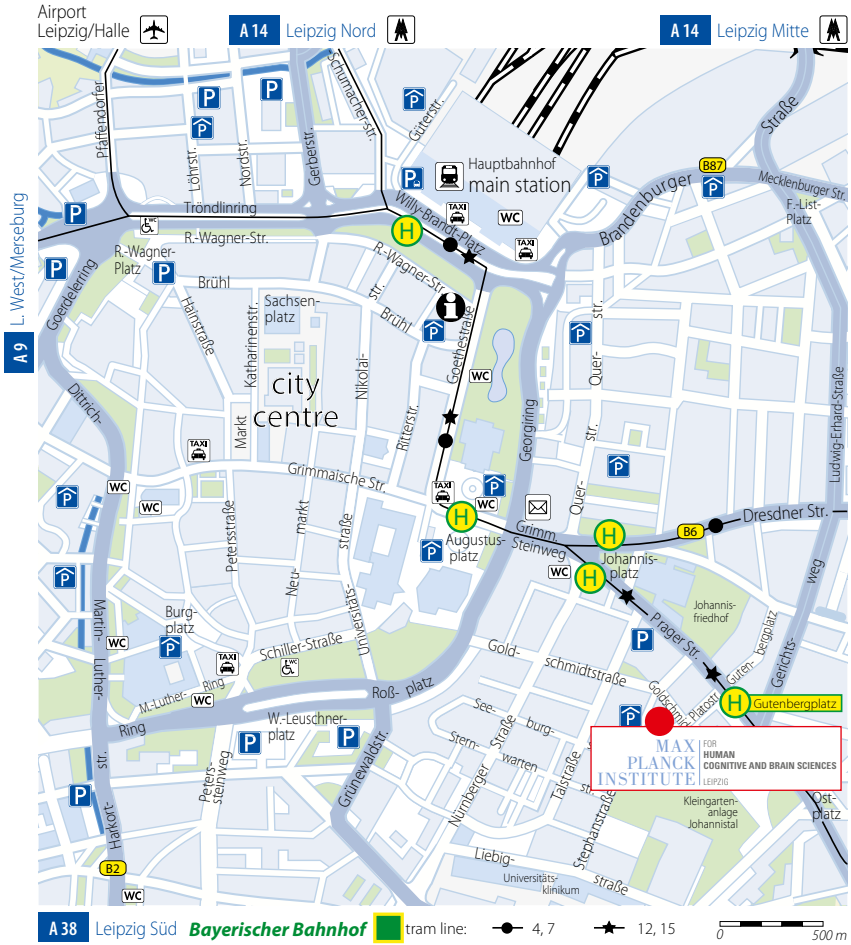
[3] Department of Psychology, Westfälische Wilhelms-Universität, Münster, Germany

	Wednesday July 13
8.45 – 9.00	**Registration**
9.00 – 9.15	Welcome
9.15 – 9.45	Henkjan Honing
9.45 – 10.15	Josephine Terry
10.15 – 10.45	Annerose Engel
10.45 – 11.10	**Coffee break**
11.10 – 11.40	Hiroshige Takeichi
11.40 – 12.10	Rudi Villing
12.10 – 12.40	Sundeep Teki
12.40 – 14.00	**Lunch (Hang up posters)**
14.00 – 14.30	Brigitta Burger
14.30 – 15.00	Sylvie Nozaradan
15.00 – 15.30	Hans-Henning Schulze
15.30 – 16.00	**Coffee break**
16.00 – 16.30	Jacques Larue
16.30 – 17.00	Jacques Launay
17.00 – 17.30	Hugo Merchant
17.40 – 19.00	**Poster Session with refreshments**

	Thursday July 14
9.15 – 9.45	Peter Howell
9.45 –10.15	Yvonne Delevoye-Turell
10.15 –10.45	Anne Giersch
10.45 –11.10	**Coffee break**
11.10 –11.40	Dirk Vorberg
11.40 –12.10	Simon Grondin
12.10 –12.40	Edward Large
12.40 –14.00	**Lunch**
14.00 –14.30	Martine Turgeon
14.30 –15.00	Geoff Luck
15.00 –15.30	Alan M. Wing
15.30 –16.00	**Coffee break**
15.30 –16.00	Alessandro Tavano
16.30 –17.00	Molly J. Henry
17.00 –17.15	**Short Break**
17.15 –17.45	Sofia Dahl
17.45 –18.15	Bruno Repp
19.00	**Conference Dinner (Bayerischer Bahnhof)**

	Friday July 15
9.15 – 9.45	Fred Cummins
9.45 –10.15	Volker Dellwo
10.15 –10.45	Michael O'Dell
10.45 –11.10	**Coffee break**
11.10 –11.40	Dirk Moelants
11.40 –12.10	Leigh Van Handel
12.10 –12.40	Guy Madison
12.40 –14.00	**Lunch**
14.00 –14.30	Igor Jauk
14.30 –15.00	Anatole Fiodorov
15.00 –15.30	Sonja A. Kotz
15.30	Closing remarks Sonja A. Kotz

City map



Conference Dinner

Bayerischer Bahnhof
Bayerischer Platz 1
04103 Leipzig