Entrainment Workshop Abstract Book

RITMO is hosting researchers for an interdisciplinary workshop on the concept of entrainment, featuring perspectives from musicology, ethnomusicology, cognitive neuroscience, music cognition, and computational modeling.

Presentations and sessions will take place in two parallel streams. The presentation parallel streams are separated into one stream which is predominantly in-person and another stream in which all presenters are remote. The predominantly in-person stream is taking place in Forsamlingssalen / YouTube and remote presentations are indicated in this stream with the label “Remote Presentation”. All presentations taking place in RITMO Meeting Room v217 / Zoom are being presented remotely.

August 17th

Presentations

9:00-10:00 Forsamlingssalen / YouTube

Modeling Rhythm Perception and Temporal Adaptation

Ece Kaya[1,2] & Molly J. Henry[1,3]

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Performing auditory tasks such as understanding speech and listening to music relies on our ability to entrain internal oscillations to those signals via mechanisms of phase and period adjustment. Here, we adopted a computational modeling approach to investigate properties of internal oscillators on an individual-by-individual basis. We fitted a linearized (canonical) oscillator model and several novel variants that we developed to empirical data obtained from a two-session duration discrimination experiment. The two experimental sessions differed regarding the temporal context: change in stimulus rate between consecutive trials was minimized in one session and maximized in the other, with the latter inducing strong history effects on perceptual judgments. The parameters of the canonical model quantified the initial (eigen)frequency of the oscillator, and the extent to which it adapted its phase and period to each stimulus interval. To capture entrainment decay in the absence of rhythmic stimulation, we added two parameters that quantified decay in oscillator period within and between trials

back to its eigenfrequency. Model comparisons showed that the full model with the additional parameters performed better than the canonical model, and models where either (but not both) of the decay parameters were implemented. We obtained individuals' parameter estimates from the winning model and compared them between the experimental sessions. Results showed that in challenging temporal contexts with changing stimulus rate, internal oscillators relied more on period correction than phase correction. Moreover, estimates for oscillators' eigenfrequencies were slower in these temporal contexts than those that required minimal temporal adaptation, paralleling the results of empirical analyses. Finally, participants who performed worse at the task had stronger decay parameters and slower eigenfrequencies. Our findings indicate that attentional synchronization to rhythmic sequences is modulated by the temporal context, and that entrainment decay in addition to phase and period correction plays a role in temporal adaptation.

Sonic Explorations for 3D Swarmalators

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A swarmalator is a type of self-organizing system where agents or particles interact with each other through local rules. The term "swarmalator" is a combination of "swarm," which refers to a group of agents, and "oscillator," which refers to a system that exhibits periodic behavior. In a swarmalator system, each agent has an internal oscillator that determines its behavior, and the agents interact with their neighbors, affecting each other's oscillations and leading to synchronization. This synchronization can result in collective behaviors such as coordinated motion or pattern formation. Both the phase dynamics and spatial dynamics of the oscillators are coupled in swarmalators. Swarmalators are related to the concept of entrainment, which refers to the synchronization of rhythmic patterns in biological or physical systems. Swarmalator systems can be used to model entrainment and the emergence of collective behavior in natural systems. Sonic and musical properties can be explored using the parameters involved in swarmalators, leading to interesting self-organized compositions and emergent behaviors capable of interacting with humans in a synchronized environment. Some of these sonical mappings will be presented for a 3D version of swarmalators, and future directions for interactive music systems based on synchronized swarms will be discussed.

A Control Systems Perspective on Entrainment *Remote Presentation*

Roger K. Moore
University of Sheffield, UK

The coordinated behaviour of large numbers of independent living organisms has been the subject of scientific enquiry for many years. For example, studies have been conducted into the flocking of birds, the synchronised flashing of fireflies, the dynamics of human crowd movement, waves of coordinated clapping by audiences, and spatial sorting in shoals of fish. An important aspect of such synchronous behaviours is that they involve parallel coupled simultaneous action, as opposed to sequential action-reaction. Such collective behaviours can thus be viewed as rhythmic entrainment, constituting a form of accommodation between individuals in a population. The most popular paradigm for modelling coordinated collective behaviour is based on coupled oscillators. However, it is only one way of formulating a complex non-linear attractor space, and it overlooks a number of potentially important conditioning variables. The work reported here investigates an alternative approach based on closed-loop negative-feedback control – a powerful regulatory mechanism with roots in 'cybernetics' and commonly deployed for stabilising engineering systems. The main differences between this approach and coupled oscillators is that the convergence criteria can be made more explicit, thereby offering the potential to gain a deeper understanding of the implications of particular parameters/settings on the emergent collective behaviours. This paper reports on a computer-based simulation in which a number of vocalising (and listening) 'agents' may be connected to each other in arbitrary network topologies. Each agent comprises two feedback-control loops: one to regulate the interaction with other agents and another to regulate the agent's own behaviour. The first of these control loops aims to maintain synchrony between an agent's own vocalisations and those from agents that it can 'hear'. The second control loop attempts to maintain the agent's own preferred vocal rhythm. The emergent outcomes demonstrate various forms of entrainment as a function of particular parameter settings.

9:00-10:00 RITMO Meeting Room v217 / Zoom

Simultaneous Tracking of Two Isochronous Beat Patterns

Dr. Patti Nijhuis & Dr. Maria Witek
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Some musical practices, such as DJing and conducting, suggest simultaneous entrainment to multiple unrelated beat patterns. However, whether this is possible is debated. To investigate this, we presented participants with two tracks of isochronous beat patterns that could not be perceived as a single metric rhythm when played together. These tracks had 1/2-meter and tempos of 114.6 or 163.8 BPM. Participants listened to either a single track or both tracks simultaneously while selectively attending to one or actively attending to both patterns. To assess their ability to track the beat patterns, participants judged whether a probe tone following the beat was in time with the beat. The probe could coincide with either pattern or neither. EEG was recorded concurrently, and a frequency tagging approach was taken. The amplitude of the steady state response at the frequency of the respective track was used to measure neural tracking strength. Our results showed that, in the dual attending condition, participants performed significantly better than chance ($p<.001$) and outperformed their predicted score assuming a selective attending strategy ($p=.01$). This indicates that individuals can track the period of more than one beat pattern simultaneously, with no significant difference between musicians and non-musicians. Preliminary EEG findings suggest that attention has a clear effect on neural responses, with the frequency-specific response (to the beat) decreasing when attentional resources are challenged during selective and dual attending compared to single track listening. Additionally, the 114.6 BPM track has overall larger frequency responses, indicating affinity for rhythms around the 2Hz preferred movement frequency. Overall, these results suggest that people can indeed track two beat patterns simultaneously, although it remains unclear whether this occurs through simultaneous entrainment to two auditory streams or through rapidly shifting attention between them while holding period information in memory.

Appeal for An Interdisciplinary Exploration of Rhythmic/Musical Entrainment in People with Alzheimer's Disease (AD)

Runa Ya
University of Cologne, Germany

Alzheimer’s disease (AD) is a neurodegenerative disease that leads to a progressive decline of cognitive functions affecting memory, orientation, comprehension, learning capacity, language, and physical mobility. According to the “Global status report on the public health response to dementia” of the WHO, AD is becoming a rapidly emerging global challenge, causing disability and dependence in older adults worldwide. At the same time, some people with AD show intact musical memory for long-known musical information and the ability to engage/entrain with music even in the later stages of the disease. Furthermore, studies show that life-long musical activity can protect against age-related cognitive decline and AD. In the clinical

context, entrainment-based neurorehabilitation (e.g., Neurological Music Therapy) has been proven effective (e.g., for Parkinson's disease, stroke). However, research concerning musical entrainment in Alzheimer's disease is sparse. To what extent are people with AD able to entrain with external rhythm? Does rhythmic entrainment induce neurogenesis and plasticity? To what extent does interpersonal musical entrainment facilitate social interaction and nonverbal communication in AD? How to investigate these questions empirically? Are third-person approaches sufficient? How to integrate the first-person perspective? In this presentation, I will briefly review the state of the research, arguing for transdisciplinary cooperation/collaboration in exploring musical/rhythmic entrainment in AD. It can 1) shed new light on our understanding of Alzheimer's disease in general and the innate human capacity to engage/entrain with music in particular, and 2) facilitate the development of new strategies for early diagnosis, prevention and non-pharmacological interventions against this emerging global challenge.

Music-Based Training for Children With Dyslexia: Preliminary Results of a Randomized Control Trial

Maria Ioanna Zavogianni[1,2], Maja Kelić[3], & Ferenc Honbolygó[1,4]

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Previous entrainment-focused interventions have shown to enhance phonological and reading skills. The current study aims to assess the effectiveness of a newly developed training for the improvement of linguistic and cognitive deficits related to reading disorder. For this purpose, we conducted a Randomized Control Trial (RCT, Clinical Trials ID: NCT05137353) with a pre-training phase, training phase, and post-training phase. We recruited children (age range: 8 – 11 years old) with dyslexia and we conducted neuropsychological, behavioral and electrophysiological measurements. The children were randomly assigned to the music or a spelling intervention and received weekly sessions in a 3-month timeline. Having been developed with specific emphasis on entrainment, the music intervention consisted of a series of music activities (i.e., rhythmic stimulations, music shapes, music reading, and music writing). The spelling intervention consisted of activities which focus on practicing spelling words in a computerized environment. Finally, the post-training phase, which matched the pre-training phase, was conducted. In the pre-training phase, we expect low scores in digit span task, reading fluency, pseudoword reading tasks, and not statistically significant Mismatch

Negativity responses during the ERPs measurements. However, in the post-training phase, we expect positive effects of the music intervention in the following domains: auditory discrimination of phonemic changes within pseudowords, phonological encoding/decoding, reading fluency. A preliminary version of the results of the study will be presented during the conference. With this study, we will be able to highlight the significance of music interventions as a remediation tool aimed for children with dyslexia; in this way, such interventions could be established as frequent practice in evidence-based practices.

10:15-11:15 Forsamlingssalen / YouTube

Auditory Steady-State Responses With Stereoelectroencephalography: Distribution and Relation to Seizure Onset Zone

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Auditory Steady State Responses (ASSRs) are oscillations entrained to periodic auditory stimuli presented either as trains of clicks, or amplitude-modulated (AM) tones. This type of evoked response has shown to be a promising biomarker for neurological disorders, with the literature showing alterations in patients with schizophrenia, bipolar disorder, and dyslexia. Recent works also show that it may be used for assisting in identifying the lateralization of epileptogenic regions. In our work, we aimed to further investigate this in epilepsy patients with depth electrode implants. We hypothesized that abnormal ASSRs elicited by amplitude-modulated (40 Hz or 80 Hz modulation rate) sounds would be present in regions close to seizure onset. Furthermore, we aimed to map the brain regions in which ASSRs were elicited. We found that ASSRs in seizure-onset contacts were rare, suggesting impaired responses due to epileptogenic circuits. In addition, we found that the sound stimuli elicited responses in superior, mesial, and transverse temporal gyri, as well as insula and postcentral gyrus.

Periodic vs Aperiodic Temporal Predictions – Shared or Separate Underlying Mechanisms?

Sandra Solli[1,2], Sabine Leske[1,3], Anne Danielsen[1,3], Anne-Kristin Solbakk[1,2], & Tor Endestad[1,2]

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The ability to accurately anticipate the timing of future events plays a critical role in guiding adaptive behavior, and the environment presents different types of predictable temporal structures. While much research has focused on periodic rhythms, the neural entrainment model has emerged as a potential neural mechanism underlying predictions based on such isochronous rhythms. According to this theory, endogenous neural oscillations synchronize with external rhythms and align the optimal phase to predicted time points. However, it remains unclear whether the role of endogenous oscillations is limited to temporal predictions driven by periodic regularities, or if it is also underlying aperiodic temporal expectations through phase alignment. In the current study, we employ auditory temporal predictions based on both periodic and aperiodic rhythms, aiming to examine the functional role of endogenous oscillatory activity in different types of temporal predictions. Our findings indicate that task performance on a tone detection task significantly improves when the presentation of the tone is phase-aligned with a preceding isochronous or accelerating rhythm, compared to a pseudo-random rhythm. However, a difference in performance between in-phase and antiphase is observed only in the periodic condition. We will show preliminary EEG results, further elucidating these behavioral findings.

Predicting the Beat Bin – Beta Oscillations Support Top-Down Prediction of the Temporal Precision of a Beat

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Acoustic temporal regularities in the environment are exploited by the brain to enable prediction of the timing of future events and to optimize sensory processing and behavior. It has been shown that periodic sensory inputs entrain oscillatory brain activity. But to what extent this mechanism is instrumental to temporal prediction and under top-down control remains debated. Most environmental periodic patterns do not show strict periodicity and vary in their temporal precision. The current study addressed how the brain predicts different degrees of temporal precision of an expected musical beat, exerting flexible endogenous control via neural entrainment according to the precision needed in the given sensory context. Adult participants detected the delay of a target sound relative to a series of preceding isochronous sounds. Using sound cues, we induced two levels of predicted temporal precision, by employing sounds with different acoustic features. The results show that the information of the cue modulated the prediction of beat precision. Pre-target beta (15-25 Hz) power and phase locking were enhanced if the listener predicted a target sound with a high compared to a low temporal precision. Importantly, pre-target beta power correlated positively with behavioral performance in the delay detection task, but negatively with the variability of the perceptual center (P-center) of sounds, providing support for a tight relation between beta oscillations and perceptual temporal precision. The study gives new insights into predictive processes underlying the flexible entrainment to different levels of temporal precision during beat perception and that these processes are under top-down control.

10:15-11:15 RITMO Meeting Room v217 / Zoom

Movement Entrainment in a Live Concert – Investigating Relationships Between Movement Entrainment, Social Experience and Prosocial Behaviour in Three Different Concert Scenarios

Maren Hochgesand & Hauke Egermann
TU Dortmund University, Germany

Previous studies suggest that shared, synchronised movement such as dancing in concerts can have positive effects on mood, social bonding, and prosocial behaviour. Still, there is a lack of studies capturing those effects evoked by entraining to music in ecologically valid live concert scenarios. The aim of this exploratory study was to investigate relationships between movement entrainment, social experience and prosocial behaviour in different concert settings. Therefore, we recorded participant responses in three live concerts. We measured acceleration data at two different locations of the body (torso and arm) of 42 participants (57.1 % female, age M = 25.61, SD = 9.31) during a rock concert. Additional data from two big band concerts

with in sum 71 participants have recently been collected (49.3 % female, age M = 29.2, SD = 10.91). After the concert we measured participants' mood, their general evaluation of the concert, social experience and prosocial behaviour. Preliminary data analysis shows significant positive correlations between movement entrainment and participants' self-report of desire to dance, the overall evaluation of the concert, positive activation, and valence after the concert. We found no significant correlations between movement entrainment and prosocial behaviour or the dimensions of the social experience of a concert, but a significant positive correlation between the desire to dance and two dimensions of social experience: solidarity and satisfaction. Contrary to previous study results, the findings indicate that movement entrainment is separated from social experience and prosocial behaviour and that they have to be seen as separate processes. Movement entrainment is more likely to be an indicator of liking the concert than of social experience and there might be other factors mediating between movement entrainment and social experience as well as prosocial behaviour. Further analysis will lead to insights if these findings can be replicated in other concert scenarios.

Synthetic vs. Live Music: Examining the Impact on Social Bonding in Modern Music Production

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Music has long been considered an important tool for social bonding, with joint music performance or ensemble performance being a key aspect of this bonding experience. As modern music production increasingly employs synthetic instruments, which lack the micro-timing, pitch, and volume variations characteristic of live human playing, it becomes critical to examine how these changes affect social bonding experiences. We conducted two experiments (n = 200), utilizing a paradigm in which participants watched videos of stick figures walking in synchrony or out of synchrony with each other and the music, and imagined themselves as one of the figures. In both experiments, we examined participants' perceived social bonding with virtual others using the Inclusion of the Other in the Self (IOS) scale, and their felt togetherness, valence, energy, and enjoyment. Both experiments also contrasted synthetic and live versions of the stimuli, with Experiment 1 focusing on solo playing, and Experiment 2 on ensemble playing. The initial results suggest a general tendency for live music, particularly in minor mode, to evoke sadder emotions when incorporated in the videos.

Live music was also generally perceived as sadder and less energetic when played without the video. Significant correlations were found between participants' responses to the videos and the corresponding responses to the auditory excerpts. These tended to be generally larger under the live condition, especially in the context of ensemble playing (Exp. 2). Further research is needed to explore the effects observed in this exploratory study, which highlighted subtle differences in social bonding experiences elicited by synthetic and live music performances. By examining the specific traits of synthetic instruments and their impact on social bonding, we might better understand the potential social effects of music generated by digital tools. As AI-generated music relies heavily on synthetic instruments, these findings may offer insights into the impact of AI-generated music on social bonding experiences.

Interpersonal Entrainment: The Morphogenic Role of Emotions

Smykovskyi Andrii, Janaqi Stefan, Bieńkiewicz Marta & Bardy Benoît
University of Montpellier, France

Human interaction entails the coordination of actions in time. In this regard, the patterns of action towards morphostatis, the tendency to stability of behavior, or morphogenesis, the tendency to change in behavior, reflect the entrainment dynamics of interpersonal coupling. Much research effort has been invested in expounding on rhythm adaptations between individuals, but the effect of systematically induced emotions on interpersonal mutual entrainment (i.e., synchronisation) remains unclear. To address this problem, we conducted a series of experiments in which we induced emotions with success-failure manipulations and quantified the resulting synchronisation changes. In the first experiment, groups of three participants spontaneously synchronised during a joint improvisational dancing task. In the second experiment, groups of three participants intentionally synchronised during a seated air finger-tapping task. Our results demonstrated that ecologically induced emotions produce discernable changes in movement synchronisation. In fact, the results of the first experiment, in which the task was personally relevant (i.e., dancing for dancers), showed improved synchronisation scores after positive emotion induction. In contrast, the results of the second experiment, in which the task was not personally relevant (i.e., air finger-tapping task), evidenced impaired synchronisation tendency after negative emotion induction. We didn't, however, detect substantial differences in physiological activity throughout different experimental tasks. We discuss implications for interpersonal synchronisation research and applied outcomes for the development of emotion-aware devices.

11:30-12:30 Forsamlingssalen / YouTube

Bodies in Concert

Laura Bishop & Finn Upham
RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo, Norway

Increasingly, research on music performance is moving out of controlled laboratory settings and into concert halls, where there are opportunities to explore how performance unfolds in high-arousal conditions and how performers and audiences interact. In this session, we will present findings from a series of live research concerts that we carried out with the Stavanger Symphony Orchestra. The orchestra performed the same program of classical repertoire for four audiences of schoolchildren and an audience of families. Orchestra members wore sensors that collected cardiac activity, respiration, and body motion data, and the conductor additionally wore a full-body motion capture suit and eye-tracking glasses. Audience members in some of the concerts were invited to wear reflective wristbands, and wristband motion was captured using infrared video recording. We will begin the session with a discussion of the scientific and methodological challenges that arose during the project, in particular relating to the large scale of data capture (>50 musicians and hundreds of audience members), the visible nature of research that is carried out on a concert stage, and the development of procedures for aligning data from different recording modalities. Next, we will present findings from two lines of analysis that investigate different aspects of behavioural and physiological coordination within the orchestra. One analysis investigates the effects of audience noise and musical roles on coherence in (i) cardiac rate and variability and (ii) respiratory phase and rate. The second analysis investigates the effects of musical demands on synchronization of body sway, bowing, and respiration in string sections. We will conclude the session with an open discussion of how live concert research might be optimized.

Moving in Time: The Effects of Interpersonal Entrainment on Ingroup-Outgroup Bonding and Social Identity

Ellen Herschel, Jonas Kaplan & Assal Habibi
Brain and Creativity Institute, Department of Psychology, University of Southern California, USA

Interpersonal entrainment (IPE) can be defined as the intentional coordination of rhythmic actions among multiple co-actors to synchronize their actions to a common external beat. More research is needed to understand the relationship between group identity and IPE. If it is true

that IPE leads individuals to change their social identity to strengthen group formation and increase social effects, is it possible to utilize IPE to reduce divides between individuals in disparate groups? Do differing group identities impact the efficacy of IPE in establishing pro-sociality among co-actors due to pre-established ingroup – outgroup biases? In this study we used a pre-post design to investigate the relationship between group identity and IPE and assesses the efficacy of IPE to reduce divides and improve pro-sociality between disparate groups. Two-person minimal groups were formed and ingroup members completed a short team-building task. Measures of pro-sociality, self-construal, and social bonding were taken before and after the drumming intervention. Groups were randomized into two conditions: a "within" condition, where participants would drum with their ingroup member, and a "between" condition where participants would drum with an outgroup member. We found a significant impact of IPE on outgroup bonding: individuals who drummed with an outgroup member felt more bonded while no differences were found between ingroup pairs. Additionally, IPE significantly increased pro-sociality towards the drumming partner following IPE, regardless of if the partner was an ingroup or outgroup member. Individuals who drummed with outgroup members experienced a significant shift in their self-construal from independence towards interdependence with their outgroup member following drumming. Our findings suggest IPE between individuals from disparate groups can lead to changes in social identity and pro-sociality that can reduce divides and improve social perceptions between IPE co-actors.

Music, Entrainment, and Social Interaction

Lawrence M. Zbikowski
Department of Music, University of Chicago, USA

On the best available evidence, humans are among a limited number of species that have a capacity for rhythmic entrainment. And among the species that have this capacity, humans appear to be unique in their use of entrainment for a range of social behaviors, including music-making. My presentation draws attention to two further cognitive capacities—neither specific to humans—that, together with entrainment, provide a basis for music-making. The first is vocal learning, through which an animal modifies an innate communicative signal to imitate sounds made by a parent or peer. The second is a capacity for sophisticated pattern matching, which allows an animal to match a sequence of movements with a sequence of sounds; in humans, this capacity also provides the basis for analogical reasoning. As with entrainment, only a limited number of species demonstrate vocal learning (humans, for instance, are unique among primates in having this trait) and only a limited number have demonstrated a capacity for sophisticated pattern matching (including parrots, chimpanzees,

and dolphins). Despite these commonalities, humans are unique in having combined their capacities for entrainment, vocal learning, and analogical thought to create sequences of patterned nonlinguistic sound that facilitate and stabilize social interaction—that is, for music-making. This ethological innovation had two significant benefits for human cultures. First, the sound sequences basic to musical utterances can be correlated with emotion processes; when a group of individuals entrains to the same sound sequences, their emotional states can also come into alignment. Second, entraining to sequences of musical sound and to physical movements correlated with such sequences supports group bonding. My proposal, then, is that combining capacities for entrainment, vocal learning, and analogical thought offered humans a powerful tool for social interaction and the development of human cultures.

11:30-12:30 RITMO Meeting Room v217 / Zoom

Effects of Sensorimotor Synchronization on Temporal Discrimination in Different Pitch Contexts

Lola-Marie Ferly[1] & Emily Graber[2]

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Temporal processing in music has been linked repeatedly with auditory and motor-related brain areas, for example in anticipating musical events and in beat tracking tasks. Sensorimotor synchronization or tapping to the beat, improves temporal discrimination performance as shown in numerous studies, through the explicit involvement of the motor system and subsequent entrainment. At the same time, time perception is influenced by musical pitch content, as revealed through tempo judgements and tempo determination tasks with music-like sequences. Therefore, we wondered if pitch would also impact fine-grained temporal discrimination in music-like sequences. We hypothesized that 1) pitch may be able to alter entrainment and bias temporal predictions, and 2) pitch content disturbing temporal processing could be counteracted by SMS to enhance entrainment and temporal discrimination. We developed a paradigm to test the effect of pitch content and sensorimotor synchronization on temporal discrimination. Participants were tasked with detecting the onsets of gradual tempo changes (accelerations of decelerations) in auditory sequences while tapping or not in 5 pitch contexts of interest: steady pitch sequences, ascending chromatic sequences, descending chromatic sequences, predictable sequence with jumps, as well as unpredictable jumping sequence of tones related to Contemporary Classical Music. Reaction time to the tempo change onset were measured and compared across conditions. We expected predictable pitch sequences to facilitate temporal discrimination, leading to lower reaction times particularly in sequences with congruent pitch and tempo changes. However, the fastest reaction times were observed for incongruent pitch and tempo changes. Globally we expected SMS to enhance all performances, while possibly interacting with the predictability of pitch, but we observed that SMS tended to increase reaction times. Future work could further connect these pitch and timing interactions to aesthetic appreciation of music containing complex auditory sequences such as Contemporary Classical Music.

Unravelling the Relationship Between Empathy, Synchrony and Social Bonding in Children's Dyadic Musical Interactions

Persefoni Tzanaki
University of Sheffield, UK

Background: A highly cited longitudinal study conducted a decade ago (Rabinowitch et al., 2013) revealed that long-term musical interventions involving interpersonal synchrony increase children's empathy. Relevant research in adults, however, has shown that empathy and synchrony might present a reciprocal relationship, with high-empathy individuals synchronising better (Novembre et al., 2019) and experiencing stronger affiliation following synchronous interactions (Stupacher et al., 2021). Although the implications of such research are significant for children's musical and social development, it remains unknown whether empathy moderates how young musical novices attain synchronisation and bond following a temporal alignment. The present study investigated the latter aspect, exploring how trait and induced empathy moderate the affiliation stemming from children's interpersonal synchrony. Methods: Following the completion of a trait empathy questionnaire (Raine & Chen, 2018), pairs of primary school children (n=125) were instructed to play on percussion instruments along with the beat of a song presented via separate headphones. In order to heighten the differences between synchronous and asynchronous interactions, half of the pairs listened to the same song at different tempi without previous notice. In addition, empathy was induced with half of the pairs being informed their partner lost their favourite toy prior to the session and asked to imagine their emotional state. Affiliation was assessed via a questionnaire before and after the interactions. Results: Although data collection is currently in progress, we anticipate finding synchronous and empathy-induced interactions exhibiting the strongest social bonding. We also hypothesize high-empathy children will be more susceptible to induced empathy, experiencing stronger affiliation toward their partners. Conclusion: This is the first study investigating the moderating role of empathy in children's musical interactions. The findings will support central predictions of a recent theoretical framework proposing that during music-making, empathy and synchronisation create a positive feedback loop, enhancing one another simultaneously (Tzanaki, 2022).

Spontaneous Intrapersonal Synchrony and the Effect of Cognitive Load

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Spontaneous INTRApersonal synchronization is the spontaneous synchronization of behaviors within an individual. It is less investigated than spontaneous INTERpersonal synchronization, which, according to Koban and colleagues, occurs to conserve computational resources; therefore, a high cognitive load, such as during a demanding working memory task, is predicted to catalyze spontaneous INTERpersonal synchronization in individuals who, for example, clap hands or walk together while performing such a cognitive load task (2019). Conservation of resources may also explain spontaneous INTRApersonal synchronization, as findings show that when tracking two different beats simultaneously, musicians combine the beats into a single composite pattern, rather than tracking them independently (Poudrier & Repp, 2013); this preference for a single periodicity to track over multiple simultaneous ones could extend beyond perception into production. We therefore hypothesize that, to conserve computational resources, the periodicities of behaviors produced by an individual (e.g., walking and clapping) will be synchronized when performed simultaneously, and even more so when cognitive load is increased. Here, we conducted two experiments. In the first, participants finger-tapped and walked. In the second, participants finger-tapped and vocalized the word 'tick' repetitively. In each experiment, the tasks were performed separately (baseline), simultaneously, and simultaneously with high cognitive load. In Experiment 1, the cognitive load was increased by counting backwards. In Experiment 2, it was by determining whether sequentially presented spatial patterns on a 6x6 grid were same or different. Preliminary results indicate higher synchronization during simultaneous tasks compared to baseline, but no further synchronization induced with additional cognitive load.

Special Sessions

13:30-14:20 MoCap Lab

Spontaneously Entraining Hexapod Robot

Marguerite Miallier[1,2,3], Timothé Rivier[1,2,4], Lars Kristian Bårdevik[2], Frank Veenstra[2], Alex Szorkovszky[1,2], Kyrre Glette[1,2]

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We present a demo of a hexapod robot that can synchronize its movements to external rhythms. The robot is built from an open-source physical design and controlled via a spiking

central pattern generator, which self-organizes to absorb simple periodic inputs. It will be used for future studies on musical interaction and adaptive multi-agent systems.

Live Streams From Evolutionary Search for Sounds

Björn Þór Jónsson[1,2], Çağrı Erdem[1], Kyrre Glette[1,2], Stefano Fasciani[1,3]
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Here we present a web interface for navigating sounds discovered during runs of evolutionary processes. Those runs are performed as a part of investigations into the applicability of quality diversity search for sounds. This audible peek into the collected data supplements statistical analysis. Such a way of communicating the current results is intended to provide an engaging experience of the data. By either listening to automatic playback of the discovered sounds, or interacting with them, for example by changing their parameters, interesting, annoying, pleasing, and perhaps useful artefacts may be discovered, modified and downloaded for use in any creative work. The application can be accessed from desktops or mobile devices at: https://synth.is/exploring-evoruns

14:30-15:20 Forsamlingssalen / YouTube

Entrainment Research and Autism Spectrum Disorder

Alicia Lucendo Noriega[1,2] & Emily Carlson[1,2]
[1]Centre of Excellence in Music, Mind, Body and Brain, University of Jyväskylä, Finland
[2]Department of Music, Art and Culture Studies, University of Jyväskylä, Finland

Autism spectrum disorder (ASD) is characterized by two dimensions: restriction of interests with stereotypical and repetitive behavior, and a deficit in interpersonal and social communication. Recent work has shown strong evidence that difficulties with motor planning, motor control and timing, particularly sensorimotor entrainment, may underlie many of the core symptoms of autism. ASD and entrainment-focused therapies thus represent an important potential application of basic and non-clinical entrainment research which should be familiar to those working in the field. The proposed workshop session will provide participants with an up-to-date overview of research relating ASD to entrainment and the key research questions that remain unanswered. We will facilitate and invite discussion on how entrainment research, particularly data collection and analysis methods developed in non-clinical settings, may be

used in studying potential music and movement interventions for people with ASD. Two new studies will be presented for discussion as examples by the presenters. One recently completed data collection comprises a mocap study in which children (n =7) diagnosed with autism received four individual music therapy with a focus on creating embodied entrainment while undergoing markerless motion capture recording using 16 Qualisys 3D Miquis video cameras. 3D markerless motion capture data was pre-processed using Theia Markerless software, and kinematic features are currently being analyzed using the MoCap Toolbox. The upcoming, longitudinal study involves young children aged 3-4-years-old (n ≈ 120), with a focus on children identified as being at-risk for ASD. This study aims at exploring the potential effect of group music intervention on social emotional development of children, specifically when showing ASD high-risk factors. This session aims to facilitate discussion and sharing of expertise related future research into this topic, stimulate creativity in discovering links between non-clinical and clinical levels of investigation, and further awareness and on-going conversation within the community of entrainment experts regarding ASD and therapeutic applications of entrainment.

13:30-15:20 Auditorium 1 / Zoom

BioPoint: Unlocking Comprehensive Physiological Data Analysis Through Multisensor Wearable Technology

Ulysse Côté-Allard
SiFi Labs Inc.
Associate professor at the Department of Technology Systems, University of Oslo, Norway

Accurately measuring and precisely timing physiological data plays a crucial role in studying entrainment. However, relying solely on a single-source of physiological data, such as electrocardiography or electromyography, limits our understanding of the phenomenon under investigation. To gain a more comprehensive understanding, it often becomes necessary to incorporate additional sensors, which adds complexity to the recording process, particularly in terms of synchronizing multiple data streams. In this demonstration session, we will explore the capabilities of BioPoint, an advanced wearable sensor-module designed to simultaneously capture a wide range of physiological signals. These signals include Electrodermal Activity (EDA/GSR), Photoplethysmography (PPG), Inertial Measurement Unit (IMU), Electrocardiography (ECG), Skin Temperature, and Electromyography (EMG). The session will focus on utilizing biosignal processing and machine learning techniques to extract meaningful metrics from the combined data collected by these sensors. Moreover, we will discuss how the

recording quality can be further enhanced using techniques such as adaptive filtering, leveraging the perfect synchronization among the different sensors present on the BioPoint.

10-min break

Breathing Together in Music, a RESPY Workshop

Finn Upham
RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo

Respiration is a subtle but inescapable element of real time musical experiences, sometimes casually accompanying whatever we are hearing, other times directly involved in the actions of sound generation. This workshop explores respiratory coordination in music listeners and ensemble musicians with respy, a new python library for evaluating respiration information from single belt chest stretch recordings. Following an introduction to the human respiratory system and breathing in music, the workshop demonstrates how the respy algorithms evaluate phase and breath type, and presents statistical tools for assessing shared information in these features of people listening to or making music together. Rather than only use aggregate statistics such as respiration rate, respy aims to elevate the details of the respiratory sequence to facilitate our exploration of how breathing is involved in musical experiences, second-by-second. Measurable coordination of the respiratory system to musical activities challenges our expectations for interacting oscillatory systems. This session will conclude with a discussion on the different categories of relationships possible between people breathing together in music.

Keynote

15:30-16:30 Forsamlingssalen / YouTube

Understanding neural entrainment using noninvasive brain stimulation

Molly Henry[1,2]

[1]Max Planck Institute for Empirical Aesthetics, Frankfurt, Germany

[2]Toronto Metropolitan University, Canada

16:45-17:45 Forsamlingssalen / YouTube

Comparing Neural and Behavioural Entrainment to Musical Rhythms Across Cultures

Remote presentation

Daniel J. Cameron[1] & Jessica A. Grahn[2,3]

[1]McMaster Institute for Music & the Mind, McMaster University, Hamilton, Canada

[2]Department of Psychology, Western University, London, Canada

[3]The Brain and Mind Institute, Western University, London, Canada

When listening to musical rhythms, humans entrain their movements to the temporal regularities (i.e., beat rates) embedded in those rhythms. The beat rate that a listener moves along to depends on the temporal structure of a rhythm, but not strictly: different individuals can entrain to different beat rates for the same rhythm. Neural responses also entrain to the beat rates of rhythms during listening and vary between individuals, although the relationship between neural entrainment and perceptual/behavioural entrainment is not fully clear. Culture is one factor that influences how listeners perceive and move to musical rhythms. For example, different cultural groups can differ in terms of which beat rates they tend to entrain to for a given rhythm, and also in how flexible their behavioural entrainment is (how many beat rates are used for a set of rhythms). In two cross-cultural experiments, participants came from Canada and Rwanda, or from Canada and the San and Hambukushu cultural groups in Botswana. In each experiment, all participants heard the same rhythms in two tasks: a beat-tapping task, and a passive-listening task during encephalography (EEG) recording. These two tasks indicated which beat rates were entrained to in behaviour (one beat rate per trial), and the extent of neural entrainment across all beat rates. We found group differences in both behavioural and neural entrainment, although these did not directly correspond—i.e., there was not a one-to-one link between neural and behavioural entrainment. However, we found in both experiments that the groups who tapped more beat rates across all rhythms also had greater average neural entrainment at the fastest beat rate (corresponding to the basic pulse,

or minimum inter-onset interval). This correspondence between behavioural flexibility and neural entrainment may indicate possible mechanisms of behavioural entrainment, flexibility of entrainment, and cross-cultural differences.

Analytical Models of Synchrony and Entrainment in Larger Groups *Remote presentation*

Caroline Palmer[1,2] & Alexander P. Demos[1,2]
[1]McGill University, Montreal, Canada
[2]University of Illinois Chicago, USA

Synchronization of sound is necessary for musical ensembles, often explained by entrainment between internal mechanisms and external auditory rhythms. Recent analytical models of synchrony in musical ensembles build on pairwise comparisons between group members, such as cross-correlations and Granger causality applied to behavioral and neurophysiological measures. Pairwise approaches to synchrony in larger groups permit comparisons with dyadic studies but do not address interactions among more than 2 individuals. We propose that a pairwise approach to synchrony has hampered theory development, given the demands on musical ensembles to interact in different subgroups over time within a single performance. We distinguish analytical approaches to group synchrony in terms of 3 classes: pairwise comparisons applied to 2 persons; conditionalized pairwise comparisons applied to multi-person groups (>2); and multi-person comparisons (>2). Only the latter can account for shifting interactions among more than 2 performers within a performance. We consider that it may be as important to understand the ceasing of entrainment between ensemble members who need to pull away or stand out from the group at specific time points, as it is to understand entrainment. Next, we discuss analytical developments for understanding synchrony and entrainment in larger groups. The first is development of nonlinear multidimensional approaches that hold promise for examining asymmetric relationships in larger subgroups like a violin-cello-piano trio in which the leader changes over time. Second, hierarchical models that capture relationships among subgroups should be extended to move away from the assumption of strict nesting within hierarchical levels, a claim that does not permit group members to hold more than one role or to move between subgroups. Finally, human-machine interactions provide alternative ways to tests models of group synchrony, such as how popular music ensembles lay down tracks with pre-recorded partners in recording studios.

Headbanging to the Beat: How the Synchrony and Identity-Relevance of Gestures Affect Musical Identity Perception *Remote presentation*

Alexander P. Demos & Zachary Melton
University of Illinois Chicago, USA

Synchrony is frequently studied by having people tap their fingers on a keyboard, but that is not how people synchronize their movements in the wild, such as at rock concerts. How one moves to the music at the rock concert is important in conveying one's social identity to others and should affect how others perceive them. Across three motion capture studies, we examined how performing gestures that demarcate a certain musical identity from another (i.e., identity-relevant gestures, such as headbanging) affects the extent to which the motion-captured performer is perceived as a fan of a specific type of music (in this case, hard rock music). We tested how the perceiver's own identification as a hard rock fan, the expertise with which the gesture is performed (expert vs novice), and whether the gesture is performed synchronously or asynchronously (15% different tempo) affect the perceptions of hard rock fandom of the performer. Finally, we examined how these gesture characteristics and perceivers' social identity affect stereotypes of warmth and competence of the performer. We found that performing identity-relevant gestures, demonstrating one's identity expertise, and moving synchronously to music all afford a gesturer's identity, warmth, and competence. Perceivers who identified as fans themselves were more likely to rate targets as fans than people who did not identify as fans. Finally, movement related cues such as identity-relevant gestures and synchrony to music were particularly effective in demonstrating identity, when other symbolic and visual cues were not present (e.g., clothing and physical appearance of person). Thus, it appears that synchrony as a social binding agent depends on how people synchronize with each other and not simply that they synchronize.

16:45-17:45 RITMO Meeting Room v217 / Zoom

A Time-Point Approach to Discussing Entrainment

Marcos Moraes[1] & Rodrigo Batalha[2,3]
[1]Departamento de Teoria da Arte e Música, Universidade Federal do Espírito Santo, Vitória, Brasil
[2]Instrumentos de Cordas, Escola de Música, Universidade Federal do Rio de Janeiro, Brasil
[3]Universidade do Rio de Janeiro, Brasil

The aim of this presentation is to contribute to the ongoing discussions surrounding the concept of entrainment by examining rhythm through the lens of the time-point concept. This approach considers rhythm to be comprised of moments defined by gestures and sound attacks, rather than a (false) parameter of sound – duration –, as mistakenly validated by music theory in the past. This theoretical paradigm was established through discourse supporting the development of a notation system, where duration became a fundamental concept in describing musical sound, silence, and temporality. However, even before the advent of Western music notation, concepts such as movement, accent, and their relationship to poetry were used to aid in the understanding of temporal aspects of music, including rhythm and meter, as evidenced by the Classical concepts of ἄρσις and θέσις (arsis and thesis). Current literature on rhythm and musical time suggests that pulses or beats are fundamental to musical temporality, forming the basis of rhythmic structure. A pulse or beat is defined as a location in time that exists independently from its function as a beginning, with multiple pulses coexisting simultaneously. To establish a time-point location synchrony, a steady pulsating line is required, within a certain tempo. Accentuation of beats or pulses express positions in a temporal hierarchy, and are considered a cognitive phenomenon independent of external intensification. By proposing a new theoretical framework for the temporality of rhythm, it becomes clear that rhythm is not only defined by a single pulsating line, but also by a hierarchical network of pulsating layers that possess varying levels of metrical accentuation – the strength or weight of a pulse is derived from binary, ternary, and other pulsating lattice structures of pulses and layers. As a result of this discussion, the main objective is to explore alternative theoretical paradigms that could inform new compositional and pedagogical strategies.

Hierarchical Motor Organization in Violin Performance: An Initial Study

John Paul Ito
School of Music, Carnegie Mellon University, Pittsburgh, USA

Listeners to music often follow some main beat, choosing from among multiple options (e.g., quarter notes or half notes). Performers go beyond this in giving the main beat a special bodily investment, feeling like they are moving from beat to beat as they perform (Ito 2021). This paper examines the impact of main-beat choice on the hierarchical organization of motor behavior. In an experiment modelled on work by Sternad and collaborators (e.g., Schaal, Sternad, Osu, and Kawato 2004), violinists played along with a metronome, feeling a main beat either every two notes or every four notes, and responding to a randomly timed signal either with a larger motion of the bow or verbally. The participants showed much stronger entrainment than seen in the previous studies, with bowed responses perturbing previous

temporal patterns only minimally. In relation to the question of hierarchy, the four-beat bowed condition had shorter reaction times; we suggest that this resulted from stronger phase attractors having been created on the strong beats in that condition. Response modes (i.e., clusters of responses) were also more concentrated in the four-beat bowed condition than in the two-beat bowed condition.

A Rhythmic Serious Game to Improve Sensorimotor and Executive Functioning in Children With Autism: Feasibility Assessment

Kevin Jamey, Hugo Laflamme, Nick E. V. Foster, Krista Hyde & Simone Dalla Bella
International Laboratory for Brain, Music and Sounds Research (BRAMS), Montreal, Canada
Dept. of Psychology, University of Montreal, Montreal, Canada
Centre for Research on Brain, Language and Music (CRBLM), Montreal, Canada

Children with autism are characterized by atypical sensorimotor functioning, compromising cognitive, communication, and social functioning. Sensorimotor training is a novel entry point for remediating symptoms related to autism. We modified a gamified music-based sensorimotor synchronization training for adults called “Rhythm Workers” to suit pediatric populations. It has been successfully used to help treat movement difficulties in Parkinson’s but has not been assessed in neurodevelopmental disorders. This pilot study tested the feasibility and acceptability of “Rhythm Workers” in children with autism. We administered an at-home longitudinal protocol across Canada in children diagnosed with autism without comorbidities. A total of 26 children (7-13 years) were randomly assigned to either a finger-tapping rhythmic game (RhythmWorkers, tablet application) or a control game (FrozenBubble) with similar auditory-motor demands without beat-synchronization (active control condition). Participants played the game for 300 minutes over 2 weeks. We collected data (self-reported and logged on the device) on various feasibility measures including compliance, motivation, perceived difficulty, emotional state, and game progression. Additionally, we administered a range of rhythmic abilities using the Battery for the Assessment of Auditory Sensorimotor and Timing Abilities (BAASTA) and executive functioning tasks for cognitive flexibility, inhibition control, and working memory. Preliminary findings using Wilcoxon rank sum tests show that both games were equally played regarding training time and game progression ($p > 0.16$). Both games were rated similarly in terms of perceived difficulty and motivation ($p > 0.23$) and required the same amount of motor activity (finger taps; $p = 0.51$). This feasibility assessment provides a suitable empirical basis for analyzing and interpreting skill transfer findings in our rhythmic and executive functioning measures. Our findings also suggest that both games are well-matched and optimized for an upcoming randomized control trial examining rhythm-based training in autism.

August 18th

Special Sessions

9:00-10:50 Forsamlingssalen / YouTube

Implementing Virtual Partners for Sensorimotor Synchronization Research

Bavo Van Kerrebroeck[1,2], Marcelo Wanderley[1], Caroline Palmer[2], & Pieter-Jan Maes[3]

[1]Input Devices and Music Interaction Laboratory (IDMIL), Department of Music Research, McGill University, Montreal, Canada

[2]Sequence Production Lab (SPL), Department of Psychology, McGill University, Montreal, Canada

[3]Institute of Systematic Musicology (IPEM), Department of Musicology, Ghent University, Ghent, Belgium

Successful music making requires communication of expressive intentions and a healthy balance of anticipation and adaptation in fine-grained spatiotemporal and embodied dynamics. As such, it represents a fertile ground to empirically test and validate behavioural models of coordination that explain synchronization and entrainment. While music research with adaptive auditory metronomes has offered fundamental insights into the (neuro)physiological processes underlying sensorimotor synchronization (Harry et al., 2023), introducing more embodied interactions allowing for expressive cues or posture mirroring could shed further light on the spontaneous processes and planned strategies in successful music making. Extended reality technology is naturally equipped for this task as its digital nature allows for flexible control of stimuli, replication of empirical testing, and integration of real-time, human animated stimuli. As such, research integrating these so-called embodied virtual agents in virtual partner paradigms has already contributed fundamental insights into the synchronization mechanisms of coordinating humans (Washburn et al., 2019). This session will demonstrate a technological pipeline to perform coordination and sensorimotor synchronization research using embodied virtual agents in a virtual partner paradigm. The session will introduce the stages of capturing, processing, and displaying multimodal stimuli as performed in an earlier study (Van Kerrebroeck et al., 2021). Specifically, motion capture data from a Qualisys system will be introduced and imported into the Unity game engine platform. This data will be used to animate a virtual human, controlled using the Kuramoto model for synchronization. Auditory

stimuli will be imported using the Ableton and Max MSP applications together with a note on latencies and data synchronization. The session will demonstrate the display of stimuli in virtual and augmented reality head-mounted displays followed by an open discussion on open questions, data logging, and multi-user setups.

10-min break

Entrainment, Free Will, and Musicking: An Enactivist Perspective

Nanette Nielsen, Remy Martin, Emil Bernhardt, & Martin Pleiss
RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo

The conundrum of free will has puzzled philosophers for the past two millennia. Does it exist, how does it manifest itself, and what can it tell us about being human? Adding to recent philosophical and neuroscientific debates on free will (Dennett 2003; Gallagher 2017; Tibet 1999), this session explores the extent to which understanding the relationship between conation and entrainment in the musicking agent can lend valuable support to a enactivist account of free will. Enactivism is a turn towards affordance-based reflective consciousness: 'freely willed action is something accomplished in the world, amongst the things that I reach for and the people I affect' (Gallagher 2017, 148). Further, for the enactivist, movement is central: aesthetic experience is an embodied kinaesthetic event which is grounded in movement, and our capacity - or incapacity - to perform certain movements (Gallagher, 2011; Gallagher, 2021). The experience of free will through musicking casts vital light on a hitherto neglected aspect within the traditional philosophical debate, namely the _embodied_ sense of free will. To engage with the affective push and pull of music - whether as a listener or a performer - is to entrain with the conative energy inherent in one's own capacity to _feel_ this push and pull. Through its invitation to movement and our ensuing interaction, musical engagement reminds us of our capacity to feel free. In an enactivist framework, the embodied feeling of freedom extends to a capacity to engage free will. Merging these perspectives with a novel 'Just Do It' account of the conative striving and energy that music can afford, we argue that to engage with music in embodied ways is a powerful way to train - and entrain - our innate ability to sense and enact free will. This one-hour session is structured as a panel with brief 10-12 minute presentations from its panel members, followed by 20-25 minutes discussion with the audience.

9:00-10:50 Auditorium 1 / Zoom

Mocap Toolbox Workshop Part 1: Introduction and Basic Features

Marc R. Thompson, Martin Hartmann & Petri Toiviainen
Finnish Centre of Excellent in Music, Mind, Body & Brain, University of Jyväskylä, Finland

The MoCap Toolbox developed at the University of Jyväskylä, is a set of functions written in Matlab for analyzing and visualizing motion capture data. It is aimed at investigating music-related movement but can be beneficial for other research areas as well. The toolbox is open-source and contains highly readable code, offering users the opportunity to adapt functions according to their needs. In this introductory session, we will describe the structure of the toolbox, the various ways in which it represents data, and give an introduction to the use of the toolbox for research and analysis purposes. Topics covered will include workflow strategies, data transformations, visualizations, kinematic and kinetic analysis, and periodicity analysis. This workshop session is of interest to anyone working with or thinking about working with motion capture data. Experience with Matlab programming is recommended but not essential. This workshop will be very hands-on. To get the most out of the workshop, participants are encouraged to bring laptops that have Matlab installed. A common motion capture data set including both individual and dyadic movement to music will be accessible to participants a few days before the start of the Entrainment Workshop. During the workshop, participants can experiment with the various functions or inquire about their own data specifically.

10-min break

Mocap Toolbox Workshop Part 2: Latest Release Features and Advanced Features

Martin Hartmann, Marc R. Thompson & Petri Toiviainen
Finnish Centre of Excellent in Music, Mind, Body & Brain, University of Jyväskylä, Finland

The MoCap Toolbox, developed at the University of Jyväskylä, is a set of functions written in Matlab for analyzing and visualizing motion capture data. It is aimed at investigating music-related movement but can be beneficial for other research areas as well. The toolbox is open-source and contains highly readable code, offering users the opportunity to adapt functions according to their needs. This session will focus on advanced MoCap Toolbox usage, including higher-order features (e.g., movement complexity or fluidity), movement coupling features, and joint animation of movement and extracted features. We will also demonstrate recently implemented features and mention future directions. This workshop session is of

interest to anyone working with or thinking about working with motion capture data. Experience with Matlab programming is recommended but not essential. This workshop will be very hands-on. To get the most out of the workshop, participants are encouraged to bring laptops that have Matlab installed. A common motion capture data set including both individual and dyadic movement to music will be accessible to participants a few days before the start of the Entrainment Workshop. During the workshop, participants can experiment with the various functions or inquire about their own data specifically.

Keynote

11:00-12:00 Forsamlingssalen / YouTube

Entrainment in natural musical performances

Martin Clayton

Durham University

Interpersonal entrainment is recognised as an important phenomenon in musical performance. In this paper I will reflect on research on this topic employing empirical methods to explore natural musical performances, and on the significance of this work for entrainment theory.

Panel discussion

13:00-14:00 Forsamlingssalen / YouTube

Panelists: Caroline Palmer, Martin Clayton, Molly Henry, Peter Keller, & Petri Toiviainen

Host: Dana Swarbrick

Definitions of entrainment vary across disciplines including mechanics, behavioural psychology, neuroscience, and biology. Generally, entrainment involves the adjustment of rhythmic signals to each other. Neural entrainment and rhythmic entrainment are common terms to distinguish the types of entrainment that occur in the brain or behaviour, respectively. Some use the term emotional entrainment to describe how individuals align their emotions with one another. Can a single definition truly encompass all crucial elements and be used across disciplines or are these disciplines using the term in ways that are too different from each other to be unified? One general definition from empirical musicology is “the process by which independent rhythmical systems interact with each other” (Clayton, 2012). The importance of this definition

is in specifying that the independent systems must generate their own, self-sustaining rhythmic fluctuations, and that entrainment is the process of their interaction and their adjustments, whether both adjust to each other (symmetrical) or one to another (asymmetrical) (ibid.). Coincidental alignment is not necessarily a marker of entrainment processes because measuring alignment does not imply that a system has adjusted to another (ibid.). Instead, measuring adjustments after perturbations may provide stronger evidence for entrainment (ibid.). Many of the measures used to capture entrainment capture some element of alignment, however they do not necessarily measure outcomes of perturbations. A panel discussion with experts on entrainment from various disciplines will aim to highlight the successes and shortcomings of the current body of literature on entrainment and how we can improve research and methods on this phenomenon. Questions will probe researchers' definitions of entrainment and its correspondences and distinctions with other related phenomena including general coordination and synchrony. Finally, we will aim to highlight the gaps that still exist in the literature and how these can be addressed with the currently available methods.

Presentations

14:15-15:15 Forsamlingssalen / YouTube

Effects of Imitative Interaction on Interpersonal Behavioral and Neural Synchronization

Kohei Miyata[1], Takahiko Koike[2], Shohei Tsuchimoto [2], Kanae, Ogasawara[2], Norihiro Sadato[2], and Kazutoshi Kudo[1]

[1]Graduate School of Arts and Sciences, The University of Tokyo, Japan

[2]Department of System Neuroscience, National Institute for Physiological Sciences, Japan

People spontaneously synchronize their movements with a co-actor when they interact visually and auditorily. Previous studies suggest that partner familiarity can affect this interpersonal synchronization. It is well-known that imitative interaction can foster social connectedness, i.e., partner familiarity. Here, we hypothesized that imitative interaction increases the occurrence of interpersonal synchronization and the mirror system, which is important for shared action representation between self and other, is involved in this increase. We designed a hyperscanning fMRI recording from two individuals during drawing a circle in the air. Twenty-nine pairs of healthy volunteers performed the air drawing task in two MRI scanners before and after an imitation task. In the imitation task, participants played an initiator and a responder alternatively and imitated each other's action of writing characters. In the air

drawing task, participants were asked to draw a circle in the air with their right index finger at their preferred frequency while watching their partner's movement. The movement was recorded by MRI-compatible video cameras and projected on a screen in the other MRI scanner so that paired participants could see each other's movement. We digitized the tips of the index finger using DeepLabCut and calculated the phase relation between paired participants. We also recorded neural activities from two individuals and investigated Inter-brain synchronization using voxel-wise correlation of functional images. As a result, paired participants tended to move their finger in-phase relationship in both air drawing task sessions. There were no significant differences between the two sessions in the mean and SD of phase angles of finger movement and movement frequency. We also found the inter-brain synchronization in the bilateral superior temporal sulcus in the second session, but not in the first session. In summary, our results demonstrate the effect of imitative interaction on interpersonal neural synchronization but not behavioral synchronization.

Quantifying Neural Entrainment While Walking to the Beat

Clara Ziane[1,2,3,5], Simone Dalla Bella[2,4,5,6], Fabien Dal Maso[1,3,5]

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A third of older adults have difficulties walking, affecting their autonomy and health. With an ageing population, developing gait therapies is imperative. Interestingly, walking to an auditory rhythm can improve locomotion. Benefits may however depend on the synchronization of brain oscillations to rhythm, a phenomenon called neural entrainment. Entrainment has however never been studied during cued gait. A novel multivariate-analysis method was used to successfully extract an entrained component from electroencephalography (EEG) during finger tapping. Our objective was to adapt and validate this method for a gait task and investigate whether beat frequency modulated entrainment. An open-access database of 20 participants equipped with 108 EEG electrodes and foot switches placed under their heels was analyzed. Participants walked on a treadmill in four conditions: with and without a metronome matching preferred cadence, and with tempo increased/decreased by 17%. Auditory-motor synchronization was quantified from foot-strike events and beat onsets. We created a spatial filter using generalized eigendecomposition to extract one component oscillating around the beat frequency from EEG. Neural entrainment was quantified by computing the component's

power and stability (i.e., standard deviation of instantaneous frequencies). Correlations assessed the relationship between auditory-motor synchronization and neural entrainment. Linear mixed models assessed the effect of beat frequency on neural entrainment. The extracted EEG component showed power peaks at beat frequencies and stable instantaneous frequencies, suggesting synchronization of brain oscillations to the beat. Additionally, auditory-motor synchronization increased as entrainment increased, showing greater motor anticipation with increased power and stability of the entrained component. Finally, entrainment was strongest with slow cues, while at fast tempi, entrainment was no different from non-cued gait. A 17% increase in tempo may make beat prediction difficult as participants stepped after the beat with fast cues. Our results link behaviour to neural oscillations, thus validating our method to quantify entrainment during gait.

An Empirically Validated Set of Metrically Ambiguous Rhythms

Matt Moore[1,2], Daniel J Cameron[3] & Molly Henry[1,4]

[1]Max Planck Institute for Empirical Aesthetics, Germany

[2]Maastricht University, the Netherlands

[3]McMaster University, Canada

[4]Toronto Metropolitan University, Canada

Musical rhythm is perceived in the context of a nested hierarchy of periodicities known as metre. Metre allows time units to be grouped into beats, and musical events that coincide with beat onsets are more predictable and perceived as more stable by listeners. One common approach to studying beat and metre perception involves the use of polyrhythms. Polyrhythms consist of two simultaneous isochronous pulse trains with rates that can be expressed as a coprime integer ratio (e.g., 3:4). Either pulse train can be perceived as the beat, which results in metrical ambiguity. However, there is evidence that listeners are strongly biased towards perceiving whichever pulse train contains binary subdivision groupings as the dominant beat. Essentially, although polyrhythms in principle permit metrical ambiguity, they do not necessarily display it empirically. Here we attempted to address this issue by surveying a complete metrical space for ambiguous rhythms. We asked listeners to tap the beat of every possible rhythm that could be constructed on a 12-unit grid, presented at two different tempos. We identified different forms of ambiguity: two groups of listeners disagreeing on how to interpret the same rhythm, or an individual's interpretation changing over repeated listenings. For a second study, we identified pools of rhythms that were either highly ambiguous or highly unambiguous. We presented these two rhythm types at a broader range of tempos and rotations, both to validate their initial classification as (un)ambiguous and to determine the optimal conditions for ambiguity to arise. We thus provide a validated pool of

maximally ambiguous rhythms that we propose may serve as a powerful tool in a broad range of experiments on beat/metre perception.

14:15-15:15 RITMO Meeting Room v217 / Zoom

Effects of Metrical Priming on Rhythm Processing Responses

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Perception of rhythmic structures is important for the development of language and music capacities, and social communication. In the current study, we measured the effects of metrical priming on rhythm processing in adults using an ambiguous rhythm that could be interpreted as in either duple or triple meter. Seventeen non-musician right-handed volunteers (aged 26.74 ± 4.31 years, 10 females), participated in this study. The experiment session consisted of four periods: Silence, Baseline, Training, and Test. The Baseline period consisted of 500 repetitions of the auditory stimulus. During Training period which is similar to the Baseline period, the experimenter tapped the subject's index finger on the table to the triple meter. Finally, the Test period started, and the auditory stimulus during this period was the same as those of the preceding two periods with the exception of occasional frequency deviants in the context of an oddball paradigm; the high-probability standard stimuli interspersed with two infrequent frequency deviants, where in one position (beat) of the stimulus sequence the 150 Hz tone was replaced by a tone of the frequency 155 Hz. Our results show that passive tapping to the triple meter during the Training period improves the power of frequency spectra of the electroencephalography (EEG) at the triple frequency in the Test period with respect to the Baseline period. In addition, both deviants on the strong beat on the duple and triple meter induced a mismatch negativity (MMN) with respect to the standard. However, the MMN corresponding to the strong beat on the triple meter was stronger in amplitude compared to that corresponding to the strong beat in the duple meter. These results indicate that passive priming of the metrical interpretation leads to an enhancement of the neural response corresponding to the targeted meter, and probably better attending to the corresponding metrical positions. These findings can have implications for interventions using priming.

From Boring to Booming: How Movie Soundtracks (and Silence) Affect our Perception of Time

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Music's ability to alter our time perception is particularly fascinating. Research on waiting times in retail settings, queue contexts, on-hold waiting situations, and time estimation of musical excerpts has demonstrated its effects. However, contrasting results exist about the role of several musical features, such as music mode, tempo, loudness, and metrical variation. When considering emotional valence and arousal, some evidence suggests that positive mood music promotes time underestimation, whereas negative affect music leads to overestimation (Bisson et al., 2009). Instead, uncertain results exist in the literature about arousal (Droit-Volet et al., 2010). Furthermore, systematic investigations have yet to be conducted within the audiovisual domain. This between-subjects online experiment (N = 565) (Ansani et al., 2021) sought to analyse the influence that four soundtracks differing in valence and arousal (happy, relaxing, sad, and scary), exerted on the time estimation of a movie scene, as compared to a no-music condition. The emotional nucleus of each viewing condition was assessed via Plutchik's wheel of emotion, whereas two sliders were used to measure the self-perceived arousal and perceived length of the video. The results showed that the control group reported the video to be shorter than the music group. Moreover, as opposed to the control group, happy, scary, and relaxation groups reported significantly longer time estimations. Subsequently, a path analysis was built having musical emotional valence and arousal as exogenous variables, self-reported affective state and arousal as mediators, and time estimation as the model-dependent variable. The results proved that the soundtracks perceived as more arousing led to time overestimation. The findings are discussed in terms of two psychological models of time perception (i.e., Dynamic Attending and Scalar Expectancy theories). Finally, a phenomenological model of time perception is proposed (Flaherty, 1999) as a plausible standpoint to explain the soundtrack's effects on time perception coherently.

Transcutaneous Vagus Nerve Stimulation and Perception of Time

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In recent studies, transcutaneous stimulation of the vagus nerve (tVNS) has been shown to improve cognitive functioning including executive functions. In turn executive functions (e.g., working memory) are linked with time perception, and engage partly common brain areas, such as prefrontal cortex, parietal cortex, and basal ganglia. Thus, tVNS may be expected to affect the processing of time. To test this hypothesis, 20 participants (14 females) performed an anisochrony detection task while stimulating the vagus nerve through the ear (cymba conchae). Participants were presented with sequences of 5 tones, and asked to identify whether each sequence was regular (same time interval between the tones) or irregular (deviation from isochrony on the 4th tone). The stimulation was delivered according to a staircase procedure, which calculated a threshold of anisochrony detection. Participants performed the task on one day while receiving tVNS, and another day with the sham condition. The results showed that tVNS improved the participants' ability to detect smaller time shifts compared to the sham condition ($t(19) = 2.495$, $p = .022$). In conclusion, the results suggest an overlap between the neural circuitries stimulated via the vagus nerve and those subserving time perception, as the participants perceived smaller shifts in the anisochrony detection task.

15:30-16:30 Forsamlingssalen / YouTube

Musical Emotions Expressed in Live Performances Dynamically Influence Limbic Brain Activity in Realtime

Sascha Frühholz

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To investigate the ability of adaptive and dynamic live music to elicit more consistent brain activity in the limbic brain system as well as in the broader neural network for processing musical emotions, we implemented a novel closed-loop music performance setup for a human neuroimaging environment. We here introduced a setup that connects the live music performance of human piano players with the neural limbic responses in listeners based on a

realtime functional magnetic resonance imaging approach. This setup had three main features: (1) piano players were asked to modulate their live music performance on 12 positive and negative musical pieces specifically composed for this experiment in order to increase and maximize amygdala activity in listeners in realtime; (2) piano music was chosen, because piano is a popular and familiar solo instrument, and pianists can play a melody with harmonic accompaniment simultaneously, both important for conveying and inducing emotions; (3) we chose the left amygdala as a target region for neurofeedback setup, as it has been shown to more reliably respond to emotional music than the right amygdala; and (4) we chose to compare neural activity during the live music performance with recordings of the same musical pieces by the same pianists. Our data show that live musical performances can evoke stronger emotions in listeners and evoke stronger and more consistent limbic brain activity in listeners. Live musical performances also lead to a stronger musician-listeners coupling pointing to strong entrainment process during live compared to recorded music.

Perceiving and Producing Rhythm With and Without Pulse

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Following from our work on time series models of tapping 91 well formed cyclic rhythms, with isochronic pulses, in which we observed poor accuracy for many, we undertook point process modelling of the propensity to tap throughout the rhythmic cycles at very fine temporal resolution (Bulger et al J Math Psychology 2022). In related earlier work, we investigated by means of 'survival' analysis the identification of phrases in electroacoustic (EA) music (mostly with sonic continuity and few discrete events) in comparison with pulsed note-based music. Here we present early analyses of a study designed to compare more systematically tapping to simple isochronic rhythms and to examples of largely acoustic music that is often viewed as 'unpulsed'. Bearing in mind the psychological demand of a tapping task, potentially interesting questions concern the features in the music that predict tapping, and its sparsity or otherwise, as compared with the earlier study of EA music.

Oscillatory Attention in Groove *Remote presentation*

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Attention is not constant but rather fluctuates over time and these attentional fluctuations may prioritize the processing of certain events over others. In music listening, the pleasurable urge to move to music (termed 'groove' by music psychologists) offers a particularly convenient case study of oscillatory attention because it engenders synchronous and oscillatory movements which also vary predictably with stimulus complexity. In this study, we simultaneously recorded pupillometry and scalp electroencephalography (EEG) from participants while they listened to drumbeats of varying complexity that they rated in terms of groove afterwards. Using the intertrial phase coherence of the beat frequency, we found that while subjects were listening, their pupil activity became entrained to the beat of the drumbeats and this entrained attention persisted in the EEG even as subjects imagined the drumbeats continuing through subsequent silent periods. This entrainment in both the pupillometry and EEG worsened with increasing rhythmic complexity, indicating poorer sensory precision as the beat became more obscured. Additionally, sustained pupil dilations revealed the expected, inverted U-shaped relationship between rhythmic complexity and groove ratings. Taken together, this work bridges oscillatory attention to rhythmic complexity in relation to musical groove.

15:30-16:30 RITMO Meeting Room v217 / Zoom

The Ramp Paradigm: A New Protocol for Uncovering Individual Differences in Walking to an Auditory Beat

Agnès Zagala, Nicholas E.V. Foster, Floris van Vugt, Fabien Dal Maso & Simone Dalla Bella

University of Montreal, Canada

Walking to the beat of an auditory stimulus seems effortless for most humans. However, recent studies suggest significant individual differences in the spontaneous tendency to synchronize to the beat. Some individuals ("responders") tend to adapt their walking pace to the stimulus while others ("non-responders") show little or no adjustment to the beat. This distinction remains to be empirically validated, and little is known about the mechanisms explaining these differences. Unfortunately, to date, there is no protocol sensitive to individual

differences in adapting to rhythmic stimuli while walking. To fill this gap, we introduce the ramp paradigm, which allows to test whether a person adapts or not to a change in a rhythmic stimulus in a gait task. In this protocol, participants are asked first to walk at their preferred cadence without stimulation. After several steps, a metronome time-aligned to the footfalls is presented. While the trial unfolds, the metronome tempo progressively departs from the participant's cadence by either accelerating or decelerating. Reliable measurement of the participant's cadence is ensured by using force-sensitive resistors and a portable Teensy device. To distinguish spontaneous from intentional step synchronization to the metronome, instructions are also manipulated by asking participants to synchronize, walk naturally or ignore the stimulus. The method aims to quantify the individual adaptation to tempo changes in a rhythmic auditory stimulus, allowing to objectively distinguish responders from non-responders. The results of a validation study comparing our method to a validated step detection method using footswitch will be presented. Ultimately, this will pave the way to the study of mechanisms driving individual differences in gait synchronization and facilitate personalization of rhythm-based interventions.

The Effect of Musical Tempo and Individual Differences on Pain Perception

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Music has been shown to mitigate pain perception in experimental and medical contexts; music is hypothesized to serve as a distraction and/or modulation of emotions and arousal. There is a lack of investigation on the impact of music's structural properties, such as musical tempo or rhythm, on pain perception. Significant inter-individual variability has been observed in the spontaneous tempi at which musicians' and non-musicians produce a musical beat, measured as spontaneous production rate (SPR). Each individual's SPRs show reduced temporal variability and may serve as indicators of an individual's optimal efficiency state. The current study examined the influence of musical tempo and spontaneous production rates on pain perception. Each participant first tapped a familiar melody at a spontaneous rate. Then musical excerpts, taken from each participant's preferred musical style, were created at specific tempo matched to the participant's SPR, 15% faster, and 15% slower. Participants experienced pain with and without music in four experimental conditions: pain without music, pain with music at the tempo of SPR, pain with music played 15% faster than SPR, and pain with music played 15% slower than SPR. On each trial, a heat thermode was applied to participants' inner arm, and participants' pain perception and cardiac activity was measured. Preliminary results indicate that pain perception ratings were significantly reduced in the presence of music compared to the absence of music. Furthermore, the "SPR" tempo 9 elicited a more substantial

decrease in participants' pain perception compared to the slower and faster tempo conditions; there was no significant difference in reported preference for the different music tempo versions. These findings suggest that musical tempo effects on pain perception are optimized at spontaneous rates that may capture entrainment of endogenous rhythms to music.

Relation Between Wanting to Move and Pleasure in a Music Listening Task: Considering Motor Activity

Marie-Andrée Richard[1,2,3], Will Azzi[1,2,3], Juliette Fortier[1,2,3], Nicholas Foster[1,2,3], Nathalie Gosselin[1,2,3] & Simone Dalla Bella[1,2,3]

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Rhythmic music can evoke pleasure and a motivation to move due to factors such as arousal and familiarity. Despite the growing literature on the relation between pleasure and wanting to move, it is still unclear if this relation is influenced by the type of motor activity. In an online study, 480 participants (18 – 83 years old) listened to a randomly selected block of 24 songs from a total selection of 264 songs. For each song, participants rated the evoked pleasure, arousal (relaxing-stimulating), and familiarity. They also reported their wanting to move (WTM, low-high) for different motor activities: moving in general, tapping, walking, running and dancing. Pulse clarity of songs was extracted using MIRtoolbox. Scores were averaged by songs. Repeated-measure ANOVA shows that music pleasure and WTM decrease as a function of the intensity of motor activity. Mixed-models revealed that pleasure and WTM are highly and positively correlated, and moderated by motor activities, in which the relation is stronger with tapping and weaker with running. Moreover, tapping is the movement having the most similar curve with moving in general. Familiarity is also a moderator, in which the relation between pleasure and WTM is stronger when music is familiar. Regression analyses show that pulse clarity, arousal and familiarity are positively linked to WTM, but only familiarity is linked to pleasure. The relation between pleasure and WTM depends on the movement type, in which tapping has the strongest link, and also the most similar curve to wanting to move in general, suggesting that tapping can be used as a task to study the desire to move, or groove. These results allow a greater understanding of music-evoked pleasure and WTM, stressing the need to consider the movement type in future research.

Closing remarks

16:30-16:35 Forsamlingssalen / YouTube