20th rhythm perception & production workshop

programme

book of abstracts

edited by
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20th rhythm perception and production workshop (rppw20) • university of jyväskylä, finland, 2025

20th Rhythm Perception & Production Workshop (RPPW20): Programme and Abstract Book

Edited by Martin Hartmann, Patti Nijhuis, Deniz Duman, Joshua S. Bamford, and Geoff Luck.

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Contents

About

RPPW is an international biannual event that brings researchers from a range of disciplines together to engage in discussions about the scientific study of rhythm. Rhythm is at the core of a wide range of human tasks, from speaking and dancing, to walking and synchronising with others. This year, the workshop will host oral presentations and posters.

More about RPPW can be found at https://www.rppw.org/.

Organizing committee

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The open-source LaTeX template, AMCOS_booklet, used to generate this booklet is available at https://github.com/maximelucas/AMCOS_booklet.

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As a community of researchers and scientists, we value diversity, inclusivity, and respect for all individuals. We strive to create a safe and welcoming environment for scientific discourse, free from bias and discrimination.

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1. Abstracts submitted to RPPW20 have been accepted and evaluated based on their scientific merit, regardless of the author's nationality, ethnicity, language, cultural and religious identity, political orientation, or other background factors.

2. We encourage participation and engagement from individuals with diverse backgrounds, perspectives, and identities. We recognize the value of diverse experiences and contributions to the scientific community.

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The code of conduct of RPPW20 is based on the University of Jyväskylä's Code of Conduct, which is available at https://www.jyu.fi/en/about-us/organisation-and-management/regulations-and-principles/code-of-conduct.

Keynote Speakers

Anna Fiveash

Junior Professor Chair
Laboratory for Research on Learning and Development, Université Bourgogne Europe, Dijon

Anna Fiveash holds a Junior Professor Chair position with the National Centre for Scientific Research in France, at the Université Bourgogne Europe (Dijon). Her research focuses on connections in the brain between music and language, specifically rhythm, prediction, and syntax. Anna was awarded the Discovery Early Career Researcher Award from the Australian Research Council to lead her project at the MARCS Institute for Brain, Behaviour and Development in Sydney, Australia, where she researched content and timing predictions in music and speech. Previous to this, she held two postdoctoral positions at the Lyon Neuroscience Research Centre in Lyon, France, where she researched rhythm processing in adults and children with and without developmental language disorders. She completed her PhD at Macquarie University in Sydney in 2017, her Masters in Music, Mind, and Technology at the University of Jyväskylä in Finland in 2014, and her Bachelor of Psychology (Honours) at the Australian National University. Through her research, Anna aims to advance our understanding of music-language connections in the brain, contributing to both theoretical knowledge and practical applications in education and speech pathology.

Erin Hannon

Professor

Psychological and Brain Sciences Program, University of Nevada, Las Vegas (UNLV)

Erin Hannon is a Professor in the Psychological and Brain Sciences program at the University of Nevada, Las Vegas (UNLV). She holds a Ph.D. in Psychology from Cornell University and was an Assistant Professor at Harvard University before joining UNLV. With 20 years of research in music cognition, her work focuses on the development of musical rhythm perception and enculturation. She investigates how rhythmic perceptual abilities and behaviors develop with age and experience, and how cross-cultural variations in the listeners musical environment influence these abilities. Additionally, she explores the development of emotional responses to music, such as groove and chills, and how individual differences in musicality relate to language, cognitive abilities, and emotion. Hannon is an expert on the cross-cultural development of music and language perception and cognition. Her research on culture-specific musical abilities has received funding from UNLV, the National Science Foundation (NSF), the Defense Department, and the Misophonia Research Fund. Her work has been published in top journals in psychology and developmental science. Beyond her research, she has provided extensive editorial service and held leadership roles at UNLV and in national and international professional organizations, contributing significantly to the field globally and locally.

Andrea Ravignani

Professor

Department of Human Neurosciences, Sapienza University of Rome

Andrea Ravignani holds a BSc in Mathematics from La Sapienza University of Rome and Masters degrees from Université Paris 1 and Universitat Autònoma de Barcelona. He completed his PhD in Biology at the University of Vienna and served as a research group leader at the Max Planck Institute for Psycholinguistics. He is currently a Professor at Sapienza University of Rome and Honorary Professor at the Center for Music in the Brain (Aarhus University). He explores why humans are musical animals and how our neurocognitive capacities for music evolved. His interdisciplinary team employs various research approaches from neuroscience, ethology, psychology, linguistics, AI, bioacoustics, and primatology. His research focuses on the evolutionary and biological bases of music cognition and vocal sound production, and their roles in the origins of music and speech in humans. He seeks the building blocks of musical abilities by studying behaviors and sounds in both humans and other species, aiming to explain why humans are musical animals. Ultimately, his research addresses fundamental questions about human nature: Are we so different from other animals? Why do we spend so much time listening to and making music when it seems to lack a clear biological functionor does it?

Petri Toiviainen

Professor
Department of Music, Art and Culture Studies, Centre of Excellence in Music, Mind, Body and Brain, University of Jyväskylä

Petri Toiviainen received his MSc in theoretical physics in 1987 and his PhD in musicology in 1996, both from the University of Jyväskylä, Finland. Since 2002, he has held the position of Professor of Music at the University of Jyväskylä. He has been a visiting professor at Cornell University and a visiting fellow at Stanford University. From 2008 to 2013, he served as the head of the Finnish Centre of Excellence in Interdisciplinary Music Research, located at the universities of Jyväskylä and Helsinki. In 20142018, he held an Academy Professorship granted by the Academy of Finland. Since 2022, he has been leading the Finnish Centre of Excellence in Music, Mind, Body, and Brain, focusing on interdisciplinary research into music cognition and its links to neurobiology. His research interests include the study of music and movement, music processing in the brain, and music information research. He has utilized motion capture and brain imaging to explore how music influences movement and brain activity. His work integrates empirical research and computational methods to investigate how music engages cognitive, emotional, and motor processes, contributing to the broader field of music cognition research.

Timetable

CT: Contributed Talk, KL: Keynote Lecture

Day 1: Monday, 16 of June

8:00–9:00	**Registration (Corridor)**		
9:00–9:30	**Welcome by Committee Chair + Music Performance**		
9:30–10:30	KL	**Petri Toiviainen** University of Jyväskylä	Embodied Dynamics of Metre Perception (Chair: Martin Hartmann)
10:30–10:50	**Coffee break (Corridor)**		
10:50–11:50	**Session 1 - Computational Approaches to Rhythm** *Chair: Martin Miguel*		
10:50–11:05	CT	**Jonathan Cannon** McMaster University, Hamilton	A model of rhythm production and rhythmic auditory stimulation in healthy and Parkinsonian basal ganglia
11:05–11:20	CT	**Patricia Hu** Johannes Kepler University, Linz	Exploring Musical Time at the Phrase, Metre and Motif Level
11:20–11:35	CT	**Juan Ignacio Mendoza Garay** University of Jyväskylä	Software for the Analysis of Interpersonal Synchronisation and Coordination
11:35–11:50	CT	**Erwin Schoonderwaldt** Qualisys AB	Qualisys motion capture solutions and applications
11:50–12:00	**Group photo**		
12:00–13:15	**Lunch (Restaurant Taide or Lozzi)**		
13:15–14:30	**Session 2 - Rhythm and Synchronisation** *Chair: Alexandre Celma-Miralles*		
13:15–13:30	CT	**Marc R. Thompson** University of Jyväskylä	Interpersonal coordination of timing in dyadic performance: exploring the effects of tempo and vision

13:30–13:45	CT	**Nashra Ahmad** Durham University	Chunking, Duration, and Cycle Length: Factors Affecting Perception of North Indian Classical Rhythmic Patterns
13:45–14:00	CT	**Maria Argyriou** University of The Aegean, Rhodes	Enhancing Rhythm Pattern Movement Skills in Pre-Toddlers through the Eurythmics Dalcroze Method: An Experimental Study Led by Undergraduate Students
14:00–14:15	CT	**Martin Miguel** McMaster University, Hamilton	Inclination to synchronize with a sound is independent of its association with movement
14:15–14:30	CT	**Anne Danielsen** University of Oslo	Musical expertise affects the rhythmic perception of sung and spoken speech syllables: The effect of top-down motor representations
14:30–14:50	**Coffee break (Corridor)**		
14:50–16:05	**Session 3 - Affect & Creativity** *Chair: Laura Bishop*		
14:50–15:05	CT	**Atilla Juliana Vrasdonk** University of Oslo	Creativity as a dimension of flow: Manipulating improvisational freedom in flamenco duos.
15:05–15:20	CT	**Laura Ferreri** University of Pavia	Rhythmic Pleasure: The Influence of Musical Hedonia and Stimulus Complexity on Rhythmic Processing
15:20–15:35	CT	**Laura Ferreri** University of Pavia	Music-induced movement synchrony modulates affective and interpersonal neural synchrony during joint music listening
15:35–15:50	CT	**Rebecca Schaefer** Leiden University	Agency in music choice and finger tapping
15:50–16:05	CT	**Zakaria Djebbara** Aalborg University	Coupled Rhythms between Brain, Body and Architecture
17:00	**Boat to Conference Dinner (departure from harbour)**		
18:30–21:00	**Conference Dinner (Savutuvan Apaja)**		
21:00	**First bus returning to Jyväskylä city centre**		
21:30	**Second (last) bus returning to Jyväskylä city centre**		

Day 2: Tuesday, 17 of June

9:00–10:00	KL	**Andrea Ravignani** Sapienza University of Rome	The evolution of rhythm (Chair: Joshua S. Bamford)
10:00–10:20	**Coffee break (Corridor)**		
10:20–11:50	**Session 4 - Neural 1** *Chair: Alessandro Tavano*		
10:20–10:35	CT	**Ségolène Guérin** Univ. Littoral Côte d'Opale	Culture-Driven Plasticity and Imprints of Body-Movement Pace on Musical Rhythm Processing
10:35–10:50	CT	**Tomas Lenc** Basque Center on Cognition, Brain and Language, Donostia-San Sebastian	Revealing rhythm categorization in human brain activity
10:50–11:05	CT	**Sandra Solli** University of Oslo	Rhythm-based Temporal Expectations: Unique Contributions of Predictability and Periodicity
11:05–11:20	CT	**Carlotta Lega** University of Pavia	Topography of functional organization of beat perception and imagery in human premotor cortex: causal evidence from a Transcranial Magnetic Stimulation (TMS) study
11:20–11:35	CT	**Joshua S. Bamford** University of Jyväskylä	Drumming in time is easy: pupillometry indicates reduced processing load during a synchronised tapping task
11:35–11:50	CT	**Pedro Neto** University of Jyväskylä	MMBB-MB: A multimodal and versatile research battery
11:50–12:50	**Lunch (Restaurant Taide or Lozzi)**		
12:50–14:00	**Poster session 1 (Booombox M103)**		
14:00–15:15	**Session 5 - Rhythm Across Cultures** *Chair: Anne Danielsen*		

14:00–14:15	CT	**Chunhan Chiang** National Chiayi University	Rhythmic Synchronization as a Predictor of Sight Word Reading in Mandarin-Speaking Children
14:15–14:30	CT	**Ferenc Honbolygó** HUN-REN Research Centre for Natural Sciences	The Effects of Folk Dance-Based Training on Children's Reading, Rhythm and Cognitive Abilities
14:30–14:45	CT	**Rainer Polak** University of Oslo	Music is multimodal: introducing a multi-data corpus of music and dance performance
14:45–15:00	CT	**Rainer Polak** University of Oslo	The musical beat is multimodal
15:00–15:15	CT	**Nashra Ahmad** Durham University	The Influence of Rhythmic Cycle Length, Cultural Familiarity, and Musicianship on the Perception of North Indian Rhythmic Patterns
15:15–15:35	**Coffee break (Corridor)**		
15:35–17:05	**Session 6 - Social & Interpersonal Rhythm** *Chair: Anna Czepiel*		
15:35–15:50	CT	**Thomas Wolf** Central European University, Vienna	Do Work Songs' Musical Features Reflect Their Role in Interpersonal Coordination?
15:50–16:05	CT	**Clément Canonne** CNRS-IRCAM-Sorbonne Université, Paris	When is it harder for musicians to resist entrainment?
16:05–16:20	CT	**Laura Bishop** University of Oslo	Individuality and collectivity in professional orchestra string sections: Gauging the strength of coordination in body motion
16:20–16:35	CT	**Finn Upham** University of Oslo	Respiratory timing in orchestral performance
16:35–16:50	CT	**Regina Saltari** University College London	Entrained in musical games: multimodal communication and flow
16:50–17:05	CT	**Dhwani P. Sadaphal** University of Vienna	The effect of temporal complexity and sensory modality on self-other representations in dyadic rhythm production
17:30–19:00	**Activities (~~picnic~~ bar & run club)**		
20:30	**Pub Crawl: Karaoke & Dance**		

Day 3: Wednesday, 18 of June

9:00–10:00	KL	**Anna Fiveash** Université Bourgogne Europe	Predicting "what" and "when" in music and speech: Effects of musical training, task, and domain (Chair: Patti Nijhuis)
10:00–10:20	**Coffee break (Corridor)**		
10:20–11:50	**Session 7 - Neural 2** *Chair: Tomas Matthews*		
10:20–10:35	CT	**Connor Spiech** Concordia University, Montreal	4/4 and Even More: Pupillometry, Groove, and Uncommon Meters Galore
10:35–10:50	CT	**Jonna K. Vuoskoski** University of Oslo	Groove and rhythmic complexity modulate internal motor simulation in response to music
10:50–11:05	CT	**Mattia Rosso** Aarhus University	Frequency-Resolved Brain Network Estimation via Source Separation (FREQ-NESS)
11:05–11:20	CT	**Wannes Van Ransbeeck** Ghent University	Neurofeedback-Driven AI for Adaptive Rhythmic Interactions
11:20–11:35	CT	**Anna M. Czepiel** University of Toronto Mississauga	How our brains process speech in noise: does rhythmic regularity enhance comprehension?
11:35–11:50	CT	**Alessandro Tavano** Goethe University, Frankfurt am Main	A sweet spot at 2 Hz for auditory perception in noise
11:50–12:50	**Lunch (Restaurant Taide or Lozzi)**		
12:50–14:15	**Poster session 2 (Corridor)**		
14:15–15:15	**Session 8 - Microtiming** *Chair: Daniel Cameron*		
14:15–14:30	CT	**Guilherme Schmidt Câmara** University of Oslo	Just Noticeable Difference Thresholds of Musical Microrhythm (Asynchrony and Non-isochrony) in Multi-Instrumental Groove-based Performance

14:30–14:45	CT	**Esa Räsänen** Tampere University	Timing and dynamics of the Rosanna shuffle
14:45–15:00	CT	**Charlotte Marie Mock** University Medical Center Tübingen	Perceptual timing precision for complex sounds improves with similarity to preceding sound context
15:00–15:15	CT	**Anne Danielsen** University of Oslo	Where is the Beat in that Complex Note? Effects of Instrument Asynchrony and Attack on the Perceived Timing of Compound Musical Sounds
15:15–15:35	**Coffee break (Corridor)**		
15:35–16:50	**Session 9 - Groove** *Chair: Maria Witek*		
15:35–15:50	CT	**Toni Amadeus Bechtold** University of Birmingham	Instant Groove & sustained Catchiness: exploring differences between Groove and Catchiness through temporal thresholds
15:50–16:05	CT	**Dana Swarbrick** University of Jyväskylä	The effects of "feeling moved" and "groove" on standstill
16:05–16:20	CT	**Eleonora Fullone** University of Pavia	The Role of Expressive vs Mechanical Music Performance in the Relationship Between Pleasure and Wanting to Move: A Behavioral and Pupillometry Study
16:20–16:35	CT	**Ji Chul Kim** University of Connecticut	Dancing to music (is) like a hurricane: groove as stabilization of rhythmic coordination by body movement
16:35–16:50	CT	**Daniel Cameron** McMaster University, Hamilton	How rhythm, bass, and social movement combine to motivate group dancing at an electronic dance music concert
17:00–18:00	**Lab Tour (Musica building)**		
17:15–18:45	**Aerial Yoga**		
19:00–22:00	**Pizza with Jam Session in Boombox (M103)**		

Day 4: Thursday, 19 of June

9:00–10:00	KL	**Erin Hannon** University of Nevada, Las Vegas	It takes a lifetime to build a dancer: The development of entrainment-related musical abilities (Chair: Petri Toiviainen)
10:00–10:20	**Coffee break (Corridor)**		
10:20–11:20	**Session 10 - Rhythm in Clinical Populations** *Chair: Rebecca Schaefer*		
10:20–10:35	CT	**Noah R. Fram** Vanderbilt University Medical Center, Nashville	Rhythmicity, visual attention, and the distinction between speech and song in autism
10:35–10:50	CT	**Alexandre Celma-Miralles** Aarhus University	Neural synchronization to music in insomnia patients
10:50–11:05	CT	**Jonathan Cannon** McMaster University, Hamilton	Learning sensorimotor synchronization through reinforcement in neural networks
11:05–11:20	CT	**Tamar Dvir** University of Haifa	The Effects of Group Interpersonal Synchrony on Young Autistic Adults in Work Environment: A Mixed Methods RCT Study
11:30–12:30	**RPPW Business meeting**		
12:30–13:30	**Lunch (Restaurant Taide or Lozzi)**		
13:30–14:30	**Session 11 - Developmental Rhythm** *Chair: Katerina Drakoulaki*		
13:30–13:45	CT	**Mohammadreza Edalati** Université de Picardie, Amiens	The influence of tempo on neural encoding of rhythmic hierarchy in neonates
13:45–14:00	CT	**Haley Kragness** Bucknell University, Lewisburg	First steps: Casting a developmental lens on human dance
14:00–14:15	CT	**Francesca M. Barbero** University of Louvain	Rhythm categorization is present in human newborns and further shaped across the lifespan
14:15–14:30	CT	**Betania Y. Georlette** Université de Picardie, Amiens	Investigating Infants' Responses to Infant-Directed Singing Using Eye-Tracking
14:30–14:50	**Coffee break (Corridor)**		
14:50–15:35	**Discussion**		

15:35–15:45	**Closing remarks**
17:00–19:00	**Sauna at Viilu (spots may be still available)**

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List of Abstracts – Talks

Day 1: Monday 16th

9:30–10:30. Keynote: Petri Toiviainen

Embodied Dynamics of Metre Perception

P. Toiviainen[1,2]

KL

[1] Department of Music, Arts and Culture Studies, University of Jyväskylä, Finland
[2] Centre of Excellence in Music, Mind, Body and Brain

Rhythm perception has long been studied through sensorimotor synchronisation tasks involving finger tapping, which have revealed much about temporal prediction and entrainment. However, such paradigms provide limited ecological validity. In everyday musical engagement, synchronisation often occurs through full-body movement. Moreover, timing mechanisms have been found to differ between discrete gestures like tapping and continuous movements such as swaying or bouncing, suggesting partially distinct neural substrates. Importantly, activation of the vestibular systemsuch as through head or torso motionappears to drive beat perception.These findings underscore the need to study spontaneous, ecologically valid movement to better understand rhythm perception in natural contexts. In this presentation, I chart a trajectory from traditional tapping paradigms to more naturalistic studies of music-induced movement, focusing on full-body responses captured via optical motion tracking. This shift introduces analytical challenges, including continuous dynamics, high dimensionality, nonstationarity, and hierarchical temporal structure. I review methodological developments for addressing these issues, including techniques for simplifying complex movement data to obtain spatiotemporal movement features that underpin rhythmic alignment. I present empirical findings demonstrating how different body parts reflect distinct metrical levels, and how musical features such as pulse clarity and spectral flux influence synchronisation patterns across the body. While previous approaches have focused on encodingmodelling how features of the musical stimulus are reflected in movement patternsan alternative is to use decoding to test whether movement contains sufficient information to infer properties of the music itself. I present recent work on decoding musical metre directly from movement, using multidimensional movement data modelled with regularised regression. This approach reveals that beat-phase information can be reliably extracted across multiple metrical levels, enabling quantification of phase locking and exposing individual differences in the embodiment of rhythm. It also opens avenues for sonification, interactive systems, rehabilitation, and performance.

10:50–11:50. Session 1: Computational Approaches to Rhythm

A model of rhythm production and rhythmic auditory stimulation in healthy and Parkinsonian basal ganglia

J. Duda[1,2]***, J. Cannon***[1]

[1] McMaster University, Hamilton, ON, Canada
[2] University of Toronto, Toronto, ON, Canada

In fMRI experiments, the basal ganglia is consistently activated by rhythm production and sensorimotor synchronization to a metronome, and conditions like Parkinson's Disease that affect basal ganglia and its dopaminergic modulation are experimentally seen to affect performance on both tasks. However, it is not clear what this circuit is actually doing during rhythm production and synchronization tasks, and what role dopamine plays. Here, we propose that this circuit may specify, maintain, and adapt the tempo with which rhythmic action (e.g. finger tapping or walking) is performed. We build a model based on previous "action selection" models of the cortico-basal-ganglia loop, altered such that cortico-basal-ganglia loops correspond not to distinct actions but to a continuum of possible action tempi. During rhythm production, tempo is selected by cortical input, and rhythmic action can be automatized to continue in the absence of cortical input if tonic dopamine levels in striatum are sufficiently high. When we model Parkinson's disease as a reduction in striatal dopamine, our model reproduces the increased variation in tapping intervals seen in Parkinsonian patients, and offers insight into the efficacy of rhythmic auditory simulation in stabilizing rhythmic gait against freezing. Our model predicts that the effects of Parkinson's disease on rhythm production variability should be largely attributable to tempo drift; by reanalyzing data from a recent experiment, we find this prediction to be accurate.

Exploring Musical Time at the Phrase, Metre and Motif Level

P. Hu[1]***, S. D. Peter***[1]***, C. Cancino-Chacón***[1]***, G. Widmer***[1]

Institute of Computational Perception, Johannes Kepler University, Linz, Austria

Prior studies have established that musical time in Western classical music arises as the product of score-based timing and performance timing. Furthermore, research has shown that musical time is structured componentially across multiple levels. Following this line, we approach musical time through a hierarchical analysis, considering three levels: the global segment level, the mid-level metrical structure, and the local motif level. At the global level, we examine larger structural elements, such as sections and segments that serve as functional units defining the overarching organization of a piece. These elements are often shaped by the underlying musical structure and harmonic progression, as performers tend to align them with formal and stylistic conventions. At the mid-level, we focus on metrical organization, including measures and beats, which connects the broader formal structure to the finer details of rhythmic articulation. This level appears to be influenced by the constraints of human perception, with metrical regularity playing a central role in supporting listener understanding and temporal expectations. Finally, at the local level, we consider individual notes within melodies or motifs, as well as subtle rhythmic variations, where performers have the most freedom to express nuanced interpretations. To investigate these levels, we employ probabilistic models on 11 professional performances of selected Beethoven Piano Sonata movements, for which we have note-level alignments between the score, performance and musicological motif, structure and harmony annotations. Through this analysis, we aim to explore how temporal structures might be disentangled across levels, offering a perspective on the interplay between musical structure, perceptual constraints, and artistic choice. By examining these relationships, we seek to better understand how performers balance structural fidelity with interpretative freedom, providing a step toward a deeper understanding of the componential organization of musical time.

Software for the Analysis of Interpersonal Synchronisation and Coordination

J. I. Mendoza Garay[1]***, N. C. Hansen***[2,4]***, P. Keller***[3]

[1] University of Jyväskylä, Jyväskylä, Finland
[2] Centre of Excellence in Music, Mind, Body, & Brain, University of Jyväskylä, Jyväskylä, Finland
[3] Center for Music in the Brain, Aarhus University, Aarhus, Denmark
[4] Royal Academy of Music, Aarhus, Denmark

Playing music as a group requires interpersonal coordination, which implies communicating information about how the music shall be played. A key part of this information is non-verbal, subtle, and composed of actions with varying degrees of independence, such as when playing together in homophony or polyphony. For example, previous research has shown that synchronisation of the swaying motion of a group of performing musicians increases towards the end of homophonic sections and in the middle of polyphonic sections, with greater overall synchronisation for the latter. This suggests that group synchronisation is greater when leadership is distributed, and in anticipation of actions requiring group effort, such as coordinating tempo decelerations and subsequent re-entries at the boundaries of musical phrases. However, related research has had important limitations: small amounts of data often collected in a laboratory (i.e., not completely ecologically valid), and focus on pairwise comparisons without much attention given to group-level behaviour. To address these limitations, the ongoing study presented here is developing software towards the analysis of interpersonal synchronisation and coordination. The analysis methods are targeted to assess different aspects of synchronisation such as phase difference and phase stability, in pairwise comparisons and group-level measures. Additionally, methods are developed to analyse coordination by assessment of non-recurrent motion. The software provides processing and visualisation options to inspect the data, and to assess the sensitivity of the methods to different aspects of synchronisation and coordination. Crucially, the system is capable of extracting motion data from video, making it possible to process recordings that are publicly available on the internet, thus providing an abundance of truly ecologically valid data. Nonetheless, it can also process tabular data collected with other devices (e.g., marker-based motion capture, accelerometry). The produced software will be free to use and publicly available.

Qualisys motion capture solutions and applications

E. Schoonderwaldt[1]

Qualisys AB, Gothenburg, Sweden

Qualisys motion capture systems offer a wide range of solutions for a exploring the relation between motion, sound and other modalities, both for in-depth analysis and real-time interactive scenarios. In this talk, we will outline the various integration- and synchronization options, and present relevant customer cases for the music and rhythm research community.

13:15–14:30. Session 2: Rhythm & Synchronisation

Interpersonal coordination of timing in dyadic performance: exploring the effects of tempo and vision

M. R. Thompson[1]***, T. Himberg***[2]

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Interpersonal coordination in dyadic musical performance requires musicians to share a similar mental model of the music's timing structure. This is reflected not only in consistent inter-onset intervals (IOIs) but also through embodied expressions, such as synchronous body sway and mimicked or complementary gestures. This study explores how violinist dyads synchronize under varying tempos and facing conditions using full-body motion capture and audio analysis. It was hypothesized that interpersonal coordination would weaken when musicians performed outside each other's visual field and that synchronization accuracy would decrease at extreme tempos (very slow or very fast). Ten violinist dyads (20 music majors total) from the University of Jyväskylä and the Jyväskylä University of Applied Sciences participated in the study. The dyads performed interactive musical scale sequences (single repeated notes, echo scale, alternating scale) at four tempos (60–150 BPM) in facing and non-facing conditions with tasks of increasing complexity. A pacing metronome was initially used to set the tempo but was removed as the musicians began their performances. Analyses focused on inter-onset-interval analysis, synchronization accuracy, stability, and movement patterns. Preliminary results show that synchronization accuracy was negatively impacted at extreme tempos, with dyads accelerating at slower tempos and decelerating at faster tempos, diverging from the metronome soon after its removal. Visual contact in facing conditions promoted greater movement and improved coordination under challenging tempos. Synchronization stability was highest in simpler tasks, such as repeated notes, and diminished as task complexity and tempo variability increased. Circular statistics confirmed strong entrainment between dyads, even as they diverged from the metronome. Social dynamics also appeared critical, as musicians often laughed at mistakes, particularly in facing conditions, highlighting the role of nonverbal and emotional cues in collaborative performance. These findings advance understanding of how visual, auditory, and social elements interact to facilitate synchrony in musical contexts.

Chunking, Duration, and Cycle Length: Factors Affecting Perception of North Indian Classical Rhythmic Patterns

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Long rhythmic cycles from North Indian Classical Music (NICM), challenge cognitive processing (Ahmad et al., 2024). Retention limit of approximately 2-seconds is observed for tones. However, NICM rhythmic cycles exceed these limits, suggesting strategies (chunking) for their recognition. Ding et al. (2018) suggest that working memory prioritises number of tones over duration. This questions the interaction between cycle-length (number of beats), cycle-duration (total time), and rhythmic-nature i.e. isochronous (ISO, regular) and non-isochronous (NI, irregular). The study aims to: 1. Investigate how cycle duration (shorter vs. longer) and number of beats (fewer vs. more) influence rhythmic perception. 3. Explore whether chunking strategies aid in recognising these cycles. Western-musicians will be recruited to ensure cultural familiarity does not bias the results. Stimuli: 4-rhythmic cycles ('Original'/N) from NICM: ISO: Kehervatal (8-beats, 4+4) and Teental (16-beats, 4+4+4+4); NI: Rupaktal (7-beat, 3+2+2) and Jhaptal (10-beats, 2+3+2+3). Each Original will be presented at 4 durations (3.5, 4, 5, and 8 secs). Test stimuli will include cycles with an additional beat (N+1) and one less beat (N-1). Task: a. Forward Discrimination Task: Pairs of stimuli presented to tell whether second pattern is 'same-or-different' to first. b. Chunking Task: Participants choose one of 5 visual representations, each showing a different rhythmic grouping. Data collection is ongoing. Results are expected by May-2025. Analysis strategies include d-prime scores for discrimination (task a). Correlation determines whether participants used chunking to discriminate. Differences between ISO and NI patterns will highlight impact of rhythmic-nature observed in most previous studies.

References

Ahmad, N., Clayton, M., & Eerola, T.(2024,preprint). The Role of Cultural Familiarity, Musicianship and Explicit learning in the perception of Long Rhythmic Cycles. https://doi.org/10.31234/osf.io/ay3tk

Ding, Y., Gray, K., Forrence, A., Wang, X., & Huang, J.(2018). A behavioral study on tonal working memory in musicians and non-musicians. PloS one, 13(8), e0201765. https://doi.org/10.1371/journal.pone.0201765

Enhancing Rhythm Pattern Movement Skills in Pre-Toddlers through the Eurythmics Dalcroze Method: An Experimental Study Led by Undergraduate Students

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Eurythmics aims to help students develop physical awareness and a deeper experience of music through training that engages all the senses, particularly the kinesthetic (Crumpler, 1982; Findlay, 1995; Juntunen, 2002; 2016). The approach often introduces a musical concept through movement before students encounter its visual representation. This sequence enhances body awareness and establishes a strong connection between rhythm and physical experience, reinforcing concepts kinesthetically. Rhythmic patterns are characterized by a consistent sequence of fundamental beats, shaped by the duration of short notes and the intensity of accentuation (Md Jais, 2017). The study aimed to improve the music pre-reading, counting, and rhythmic awareness of 48 children from public preschools (Rhodes), aged 2.5 to 3.5 years. Through quantitative analysis, the study identified a significant improvement in the children's results from pre-test to post-test, comparing two groups of pre-toddlers taught by different undergraduate students (November 2024, Department of Pre-School Education & Educational Design, University of The Aegean). The children were divided into two experimental groups, EG 1 (n = 20) and EG 2 (n = 28), alongside a control group (CG) (n = 18). The undergraduate students' intervention involved implementing 15 to 20 minutes of unstructured movement time, either accompanied by singing rhythmic patterns (EG 1) or using recorded music (EG 2), five times a week. The control group continued with the standard daily music program to assess specific rhythmic skills, such as the imitation of spoken rhythmic phrases and synchronization of movement with musical rhythm. Departments of Higher Preschool Education working with children of this age must acknowledge the importance of movement in music education and the positive impact of music-movement programs. Our research findings suggest that, even in the absence of vocal training, incorporating recordings into musical-movement activities can enhance children's rhythmic abilities.

Inclination to synchronize with a sound is independent of its association with movement

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Humans can be great at focusing their attention on relevant task information while ignoring distractions (selective attention task, cocktail party problem). Yet, we may sometimes change our behavior depending on our internal representation of the task and the distractors (social Simon effect, involuntary gait synchronization). In sensorimotor synchronization, we hypothesized that a key element of involuntary synchronization to an auditory distractor is identifying it with our own actions. Under this hypothesis, participants' tapping would be more attracted to distractors associated with action. In a previous series of experiments, we tested this hypothesis using a SMS task where participants were asked to tap in synchrony to a target metronome while a lagged distractor metronome with a different timbre and pitch was also present. We manipulated the internal representation of the distractor sound (motor; non-motor) and distractor-to-metronome lag. To induce a specific representation of the distractor sound, participants performed priming tasks: counting sounds or tapping to produce the sound that would become the distractor (non-motor and motor condition, respectively). We carried out two studies where we inspected changes in mean asynchrony between conditions within participants. We only found an effect of distractor lag, replicating previous work. Bayesian ANOVA analysis found moderate evidence of no effect of representation ($BF10 < 0.3$). Our previous results indicate that timing of the distractors is processed independently to its motor representation. In our next work, we seek to verify this result by having participants ignore a distractor with an increased motor representation: their own voice. In this paradigm, participants are required to synchronize to the target metronome by producing a syllable (tah or tih). The distractor metronome is comprised of the non-produced syllable in their own voice. Motor representation of the voice is manipulated by pitch-shifting (no pitch-shift for motor condition, pitch-shift for non-motor condition).

Musical expertise affects the rhythmic perception of sung and spoken speech syllables: The effect of top-down motor representations

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Previous research (Danielsen et al. 2022) has shown that musical expertise affects the perception of the temporal location (i.e., P-center) of an instrumental sound. Here we extend this research to the context of vocal music. In two experiments expert singers in jazz and classical genres were presented with a range of stimuli, including neutral Stimuli (e.g., noise bursts, clicks), vowel sounds sung by jazz and classical singers, and spoken versions of the vowel sounds. As with our previous study, neutral stimuli produce largely the same responses in both participant groups, while a linear mixed model showed that jazz participants placed their p-centers earlier (22 ms; p=.044) and with lower variability (21 ms; p = .025) than classical participants. Contra our hypothesis, the between-group differences for P-center location and variability persisted in the context of spoken sounds. Why should this be so? Expert musicians develop highly specific motor representations of their own actions and use them when singing and playing. For singers, these these models overlap with speech production more generally. This could explain the carry-over to speech stimuli. Likewise, the vocal stimuli presented our participants with not only acoustic cues for the P-center location of the sounds themselves, but also cues for synchronizing individual actions in performance (coordinating the behaviors that produce the sounds with others). This indicates that the vestiges of joint action that remained in our experimental context were enough to engage their top-down sensorimotor models, as would be used in an actual singing or speaking context.

14:50–16:05. Session 3: Affect & Creativity

Creativity as a dimension of flow: Manipulating improvisational freedom in flamenco duos

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The "flow" state is often desired during creative and athletic activities, serving as an intrinsic motivator for enhanced immersion and performance (Csikszentmihalyi, 1996). While improvisation is known to promote flow (Limb & Braun, 2008; Luzcnik et al., 2021), the impact of varying degrees of improvisational creativity on flow intensity remains unclear. This study aims to address this gap by examining flow in professional flamenco dancers and musicians, who are traditionally trained to improvise together, making it an ideal art form to study these concepts in both domains. Eleven duos of flamenco musicians and dancers were instructed to perform a rehearsed piece, freely improvise, or combine improvised and rehearsed parts on two rhythmically and emotionally distinct flamenco palos (genres). Video and audio recordings were collected, and participants provided subjective ratings of their experience after each performance. The linear mixed model (LMM) analysis on reported ratings revealed that highest flow was experienced during free improvisation, followed by mixed performances and rehearsed performances, suggesting that flow intensity can be influenced by varying degrees of improvisational freedom. Furthermore, highest flow was experienced when pairs received the same instruction, underscoring the importance of shared goals when improvising. Moreover, a positive linear relationship between flow and connection with the partner, improvisational creativity, absorption by activity, fluency of performance and rhythmic complexity was found. The results demonstrate how improvisational freedom can be linked to the quality of the creative output and can influence the intensity of the flow experience in performing flamenco duos. The multifaceted nature of flow and the significance of group dynamics, individual focus and creativity in achieving this state within an improvising ensemble are emphasized. With these findings we propose extending Csikszentmihalyi's two dimensional model of flow (Csikszentmihalyi, 1990) by adding creativity as a third dimension.

Rhythmic Pleasure: The Influence of Musical Hedonia and Stimulus Complexity on Rhythmic Processing

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Rhythm emerges naturally in humans from infancy and plays a crucial role in cognitive functions and emotional experiences. Notably, rhythm's movement-inducing properties are thought to modulate reward responses to music. Growing evidence highlights the importance of rhythm complexity in shaping musical pleasure, with medium-complexity rhythms eliciting the highest enjoyment compared to low- or high-complexity rhythms. However, musical pleasure is not experienced uniformly across individuals, as people differ in how they derive reward from music (the so-called musical hedonia). Through a series of behavioral experiments, we investigated how music reward, in terms of both musical hedonia and pleasure-driving rhythm complexity, influence rhythmic skills. In Experiment 1 (N=121), an individual differences approach revealed that higher musical hedonia is associated with enhanced rhythmic processing for both perception (on/off beat detection task) and production (finger-tapping task) abilities. In Experiment 2 (N=120), we found that the medium pulse entropy of brief musical sequences, as a measure of rhythmic complexity, positively predicts subjective pleasure ratings, particularly in individuals with high musical hedonia. In Experiment 3 (N=135), we demonstrated that pulse entropy also influences rhythm perception: at medium pulse entropy, participants are likely to perceive stimuli as on beat, with this effect being strongest for high music-evoked pleasure ratings. Altogether, our findings suggest that music's inherent structure interacts with individual music reward profiles to influence rhythmic processing abilities, thus highlighting the complex interplay between rhythm and reward.

Music-induced movement synchrony modulates affective and interpersonal neural synchrony during joint music listening

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Music is one of the most rewarding stimuli in human life, with a unique ability to induce movement. Simply listening to music engages the dopaminergic mesolimbic system and motor areas of the brain. In daily life, music is frequently shared and experienced in social contexts, demonstrating a remarkable capacity to synchronize individuals' movements and emotions during joint listening. Despite these findings, the relationship between music-induced shared movements and affective responses, as well as their influence on neural synchronization, remain poorly understood. In this study, dyads of friends (N = 34, mean age = 21.4 $\pm$ 3.6 years, non-musicians) listened to music together while seated face-to-face. Their prefrontal cortex (PFC) activity was monitored using two 22-channels functional Near-Infrared Spectroscopy (fNIRS) devices, and their movements were recorded via video. Participants provided real-time pleasure ratings during the music listening, and the correlation between ratings given by each member of a dyad were computed as a measure of affective synchronization, referred to as pleasure similarity. Neural activity measures enabled the calculation of Interpersonal Neural Synchrony (INS) values through Wavelet Transform Coherence analysis. Video data were used to manually extract occurrences of shared behaviors, namely the number of eye contacts and shared smiles between friends. Results revealed that the higher the pleasure similarity within the dyads, the higher the INS ($p = 0.014$), demonstrating a link between affective and neural synchrony. Interestingly, pleasure similarity was positively predicted by shared smiles ($p = 0.009$), while eye contact did not ($p > 0.5$). In currently ongoing Motion Energy Analysis, upper-body movement synchrony within a dyad is expected to positively modulate the relationship between pleasure similarity and INS. These findings provide valuable insights into the multi-layered synchronising effects of music, unveiling the impact of music-driven shared movements on affective and neural synchrony.

Agency in music choice and finger tapping

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Musical agency, or the sense of autonomy or control in choosing one's own music, is gaining increasing research attention as a relevant factor for healthcare settings. Previous findings report effects of agency on pain experience, or the ability to do concurrent tasks, but the underlying cognitive mechanisms are still under debate. We investigated whether agency affects finger tapping indices using three sound conditions (metronome (M), experimenter-selected music (ESM), and self-selected music (SSM), while tapping as a single (ST) or dual-task (DT), with a concurrent n-back working memory task. Based on previous findings, we expected more consistent tapping and reduced dual-task cost (DTC) for SSM compared to both ESM and M. Fifty adults (M(age)=22.2, SD=4.0; 77% female) tapped on a midi-pad, and completed a battery of cognitive and motor tasks together with questionnaires on musical background and ratings of their experience. Tapping was indexed with the coefficient of variation (CV) and tapping force, with 5 ppts either missing data or producing insufficient taps for analysis. Although both musical conditions led to significantly higher liking and induced positive valence than the metronome control condition, the cueing conditions did not differ in CV or force, either in the ST or in DTC. SSM only significantly differed from ESM in familiarity, which is unsurprising. While the absence of an effect of agency on tapping precludes a clear interpretation, the subjective ratings indicate that the ESM was well-liked, which may have confounded an effect of agency. Furthermore, as agency did not affect DTC, there is no evidence for working memory-based cognitive facilitation. However, as all stimuli were strongly beat-based and only on-beat tapping was evaluated, the task's relative ease may have obscured clear interference effects. Future work on more complex movements and disliked ESM may address these issues.

Coupled Rhythms between Brain, Body and Architecture

Z. Djebbara[1]***, D. C. Huynh***[1]***, F. Behzadi***[1]***, A. Kalantari***[1]***, S. Louring***[1]***, L. B. Fich***[1]

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Architecture is often conceptualized through two opposing perspectives: either as a static, objective composition of matter that acts upon passive observers, or through human-centered design that reduces architectural space to a passive backdrop shaped entirely by human needs and intentions. The first view overstates environmental determinism by portraying architecture as an autonomous force that molds human experience, while the second view places excessive emphasis on human agency by treating architecture merely as a product of anthropocentric requirements, neglecting its inherent material and spatial properties. Drawing from embodied and dynamical approaches in cognitive neuroscience, we propose a conceptualization of architecture as a relational phenomenon mediated through rhythmic interactions. Endogenous neural and physiological rhythms shape architectural perception, while architectural rhythms, i.e. patterns and repetitions, modulate neurophysiological processes, establishing a dynamic system from which patterns of cognition and behavior emerge through environmental coupling. We propose that architectural influence can be quantified through simultaneous measurement of neural, physiological, and environmental rhythms. This system can reveal a complex dynamical landscape, where variables of brain, body, and environment converge toward stable patterns of interaction. This approach both allows us to reconsider automatic, unconscious responses to architecture, and provide a clearer vocabulary for describing physical settings beyond subjective impressions or abstract formal analyses. By understanding the relationship between physiological and built rhythms, interactions with architecture transcend mere unidirectionality and evolve into a dynamic dialogue, wherein the rhythms of space and body influence one another. We conclude that conceptualizing architecture through rhythmic dynamics offers a novel theoretical framework that aligns with contemporary embodied approaches in neuroscience while providing new methodological tools for understanding architecture's role in shaping human experience, perception, and behavior. This perspective positions architecture as an active participant in cognitive processes rather than a passive backdrop or mere cultural artifact.

Day 2: Tuesday 17th

9:00–10:00. Keynote: Andrea Ravignani

The evolution of rhythm

A. Ravignani[1]

KL

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Who's got rhythm? And why are we such musical, chatty animals? Human music and speech are peculiar behaviours from an evolutionary biology perspective. Notably, they both feature a rhythmic component. Many hypotheses try to explain the origins of our rhythmic capacities, but few are empirically tested and compared. Neither brains nor cognition fossilize, and lacking a time machine, the comparative approach provides a powerful tool to tap into human (pre)history. Notably, behaviours that are homologous or analogous to human rhythm can be found across a few animal species and developmental stages. Hence, investigating rhythm across species is not a zoological endeavour; it is key to unveil when the building blocks of rhythm appeared in human evolution. In this talk, I will introduce the major hypotheses for the evolution of rhythmic capacities in humans and other animals, which link acoustic rhythms to vocal learning, gait, breathing, or group coordination. I will suggest how integrating approaches from ethology, psychology, neuroscience, modelling, and physiology is needed to obtain a full picture. I will then zoom in on some crucial species which are key to test alternative hypotheses on rhythm origins. I will present data from marine mammals and primates (including humans), suggesting that cross-species rhythm research should include ecologically-relevant setups, combining strengths from human cognitive neuroscience and behavioural ecology. These results suggest that, while the full package may be uniquely human due to an interplay between biology and culture, many mammals share one or more building blocks of human rhythmicity. Biological biases amplified by cultural transmission would result in human rhythm as we know it.

10:20–11:50. Session 4: Neural 1

Culture-Driven Plasticity and Imprints of Body-Movement Pace on Musical Rhythm Processing

S. Guérin[1,2,2]***, E. Coulon***[2]***, T. Lenc***[3,2,2]***, R. Polak***[4]***, P. Keller***[5]***, S. Nozaradan***[2]

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Music compels humans to move with its rhythmic structure. In turn, concurrent synchronised body movement can shape rhythm perception spontaneously, and this short-term online effect is likely influenced itself by lifelong cultural experience. However, clear experimental evidence for this short- and long-term shaping of rhythm processing through movement is still lacking. To address this gap, we present a programmatic registered report where we recorded separately electroencephalography and hand-clapping responses to a highly syncopated and metrically bi-stable rhythm derived from West/Central African musical repertoires. These responses were compared between two groups of participants differing in cultural background, namely West/Central Africa and West Europe. The recordings were conducted before and after a body-movement session that involved stepping and clapping along with the rhythm following a cued beat (either three or four beats per rhythmic pattern cycle, the latter being congruent with original music-cultural conventions). Behavioural results revealed a significant short-term effect of body movement in African participants. Specifically, African participants clapped the beat overall more consistently and closer to the rate cued in the preceding body-movement session. Cross-cultural comparison showed greater propensity of African participants to clap the beat both before and after the cuing according to the culturally valid interpretation of the rhythmic pattern. In contrast, European participants displayed overall less stable clapping, and no significant short-term effect of body movement. Finally, inconsistencies between brain and behavioural outcomes in both groups suggest that a brief body-movement session is not sufficient to generally stabilise a beat interpretation that can be automatically reactivated in neural activity after the movement cessation, especially in response to a highly syncopated rhythmic pattern as used here. However, when participants are compelled to move to such a complex and context-free but culturally familiar rhythm, they actively mobilise the learnt beat–rhythm association to guide movement timing.

Revealing rhythm categorization in human brain activity

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Human experience of musical rhythm is fundamentally determined by the ability to map the sheer diversity of possible rhythmic sensory inputs onto a finite set of internal rhythm categories. Yet, the nature and neural basis of rhythm categorization remain largely unknown. Here, we present a novel approach allowing to reveal rhythm categories from brain activity using scalp electroencephalography (EEG) combined with frequency-domain and representational similarity analysis (fRSA). Using this approach, we provide first direct evidence for neural categorization of rhythm in humans. We show that EEG activity elicited by a set of two-interval rhythms goes beyond mere tracking of acoustic temporal features and, instead, reflects two discrete categories that encompass small integer ratio rhythms reported in prior behavioral work. Importantly, we show that these neural categories are remarkably similar to the categorical structure captured in sensorimotor reproduction of the same stimuli, yet they can emerge automatically, without a related explicit task, thus independently from motor, instructional or decisional biases. To go a step further, we investigated whether the automaticity of this phenomenon could be related to an early emergence of rhythm categories in the subcortical brain regions as a consequence of low-level physiological mechanisms. To test this hypothesis, we used a functional localizer allowing to isolate EEG activity originating from higher-level cortical vs. subcortical auditory sources. Preliminary results indicate that while the categorical representations observed at the cortical level cannot be fully explained by subcortical responses, rudiments of rhythm categorization might already emerge in the early stages of the ascending auditory pathway. Together, these results and methodological advances constitute a critical step towards understanding the primitives and biological roots of musical rhythm,

particularly the relative contribution of universal neurobiological constraints shared across species and experience-driven plasticity developing over the course of life.

Rhythm-based Temporal Expectations: Unique Contributions of Predictability and Periodicity

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Anticipating events and focusing attention accordingly are crucial for navigating our dynamic environment. Rhythmic patterns of sensory input offer valuable cues for temporal expectations and facilitate perceptual processing. Rhythm-based temporal expectations may rely on oscillatory entrainment, where neural activity and perceptual sensitivity synchronize with periodic stimuli. However, whether entrainment models can account for aperiodic predictable rhythms remains unclear. Our study aimed to delineate the distinct roles of predictability and periodicity in rhythm-based expectations. Participants performed a pitch-identification task preceded by periodic predictable, aperiodic predictable, or aperiodic unpredictable temporal sequences. By manipulating the temporal position of the target sound, we observed how auditory perceptual performance was modulated by the target position's relative phase relationship to the preceding sequences. Results revealed a significant performance advantage for predictable sequences, both periodic and aperiodic, compared with unpredictable ones. However, only the periodic sequence induced an entrained modulation pattern, with performance peaking in synchrony with the inherent sequence continuation. Event-related brain potentials corroborated these findings. The target-evoked P3b, possibly a neural marker of attention allocation, mirrored the behavioral performance patterns. This supports our hypothesis that temporal attention guided by rhythm-based expectations modulates perceptual performance. Furthermore, the predictive sequences were associated with enhanced target-preceding negativity (akin to the contingent negative variation), indicating enhanced target preparation. The periodic-specific modulation likely reflects more precise temporal expectations, potentially involving neural entrainment and/or more focused attention. Our findings suggest that predictability and periodicity influence perception through distinct mechanisms.

Topography of functional organization of beat perception and imagery in human premotor cortex: causal evidence from a Transcranial Magnetic Stimulation (TMS) study

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Humans can flexibly extract a regular beat from complex auditory patterns, such as music. Contemporary models suggest that the premotor cortex (PMC) and supplementary motor area (SMA) play a crucial role in beat perception and imagery. However, the precise contribution of these motor planning regions, as well as potential hemispheric specialization, remains unclear. To address this, we conducted a series of experiments combining behavioral assessments with transcranial magnetic stimulation (TMS) to investigate the causal role of the PMC in beat perception and imagery. After validating our stimuli in two behavioral experiments, we applied repetitive online TMS over a predefined grid, targeting the right rostral and caudal dPMC, SMA, pre-SMA, and a sham location over the primary motor cortex. Results from Experiment I revealed that stimulation of the right caudal dPMC selectively disrupted beat perception compared to all other regions. Experiment II confirmed a hemispheric asymmetry, showing that only right dPMC stimulation impaired beat perception. Experiment III further demonstrated that stimulating the same right dPMC region significantly affected rhythm imagery, particularly in more difficult conditions. Additionally, across all three experiments, individual differences in musical reward sensitivity predicted beat perception and imagery performance. These findings align with recent models emphasizing the dorsal auditory stream's role in beat-based temporal perception and imagery. They highlight the right dPMC's critical involvement in generating internal action predictions and perceptual expectations for sequential auditory events, reinforcing the dominant role of the right dorsal stream in auditory-motor integration for rhythm perception and imagery.

Drumming in time is easy: pupillometry indicates reduced processing load during a synchronised tapping task

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Interpersonal synchrony often leads to social bonding effects, but the mechanisms behind these effects remain poorly understood. One possibility is that synchrony reduces processing load, and that the synchrony-bonding effect could be understood as a general processing fluency effect. We tested this hypothesis across two studies using pupil dilation as a measure of processing load. In the first study, 104 participants completed a drumming task in a within-subjects design with three conditions (synchrony, non-synchrony, and a control with a single stimulus) in which they also completed a secondary visual attention task. We found that when drumming in non-synchrony, performance was worse on the secondary task, indicating increased cognitive load. Mean pupil diameter was also larger in non-synchrony compared with the other conditions. In the second study, 82 participants performed a similar drumming task with three conditions defined by tempo ratios as an operationalisation of synchrony (1:1, 2:3, and 256:243), however instead of the secondary task they were asked to self-report how difficult they found the tapping task and how much they liked the person they were drumming with. Participants reported that drumming in 1:1 felt easier and produced greater feelings of social connection than drumming in 256:243, but there was no difference with 2:3. Similarly, mean pupil diameter also indicated reduced processing load in 1:1 compared with 256:243 but no difference with 2:3. Taken together, these studies suggest that synchrony may promote processing fluency, which in turn leads to prosocial effects. These results also support the use of pupillometry in measuring processing load during rhythmic entrainment tasks, although limitations and challenges of this method will be discussed.

MMBB-MB: A multimodal and versatile research battery

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Music psychology relies on the accumulation of knowledge from different research paradigms. However, the impact of music on cognition, emotion, body movement and society have mostly been addressed in isolation, directed to narrow age groups, cultures, and clinical populations (e.g., Seashore, 1956; Peretz et. al, 2021). As a consequence, prevailing scientific models are often constrained by a lack of cohesion between constructs such as melody (Peretz et. al, 2021), auditory prediction (Koelsch, et., al, 2019), and emotion (Juslin, 2013). Here we propose the Music, Mind, Body and Brain - Music Battery (MMBB-MB), a research tool committed to improve naturalistic, inclusive, cross-sectional, and large sample studies in the field of music psychology. The battery has an open source and cross-platform implementation, optimized for internet browsers and mobile phones, which makes it a versatile tool for both laboratory and field studies. MMBB-MB constitutes a set of six sub-batteries: Rhythm, Singing, Movement, Emotion, Perception, and Musical Background, targeting beat perception, sensory-motor synchronization, singing performance, emotion recognition, melodic memory and musical habits throughout every stage of life (childhood, adolescence, adulthood, late adulthood), including populations with different psychiatric and neurological disorders. Each sub-battery is composed of previously validated psychometric tasks (e.g., Beat Tapping - Dalla Bella et al, 2017), or of original ones, such as those that leverage smartphone technologies for capturing full-body motion. MMBB-MB is a versatile tool that explores a broad spectrum of music-related constructs, and enables researchers to work with participant samples that are more heterogeneous in terms of age, culture, location, and health status. The battery seeks to reveal universal aspects of music capacity, as well as its dynamics across stages of life, and in different developmental, psychiatric, and neurological disorders.

References

Koelsch, S., Vuust, P., Friston, K. (2019). Predictive processes and the peculiar case of music. Trends in cognitive sciences, 23(1).
Juslin, P. (2013). From everyday emotions to aesthetic emotions: Towards a unified theory of musical emotions. Physics of life reviews, 10(3).
Peretz, I., Bolduc, J., Couvignou, M. (2021). Montreal Evaluation of Musical Abilities on tablet for 4 to 6-year-old children.
Dalla Bella, S., Farrugia, N., Benoit, C., Begel, V., Verga, L., Harding, E., Kotz, S.

(2017). BAASTA: Battery for the assessment of auditory sensorimotor and timing abilities. Behavior Research Methods, 49.
Seashore, C., Lewis, D., Saetveit, J. (1956). Seashore measures of musical talents.

14:00–15:15. Session 5: Rhythm Across Cultures

Rhythmic Synchronization as a Predictor of Sight Word Reading in Mandarin-Speaking Children

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INTRODUCTION The linguistic prosody of different languages shares the similar acoustics feature of the fundamental frequency, but different supra-segmentations, such as strong-weak pattern and high-low tone, inform each speech rhythm in English and Mandarin Chinese, respectively. Research evidence showed that the sensitivity of musical rhythm perception was related to reading development in typically developing and dyslexic Mandarin-speaking children. However, less research focuses on rhythmic production, especially in Mandarin Chinese. Rhythmic production could be a potential precursor for predicting reading development that is still underexplored in Mandarin. Therefore, this study attempts to establish valid indicators for predicting Chinese reading. METHOD Forty-six 1st and 2nd graders from Taiwan elementary schools were recruited in this study. The participants engaged in a regular isochronous tapping task to measure rhythmic synchronization. In this task, they were instructed to synchronize their finger taps with an auditory stimulus emitted from a laptop. The regular rhythms were presented for 20 seconds (paced) and 20 seconds of silence (un-paced) in various frequencies (1 Hz to 2.5 Hz). During the silence, the participants continued to tap at the same tempo as they followed before, until they heard the next regular rhythm and then tapped with it. Besides, sight word reading, phonological awareness, orthographic awareness, and rapid digit naming speed of all participants were also measured. RESULT and CONCLUSION The results showed that sight word reading strongly correlated with tapping synchronization and orthographic awareness but not phonological awareness and naming speed. The stepwise regression revealed that tapping synchronization could significantly predict sight word reading after orthographic awareness with controlling age and non-verbal IQ. In conclusion, not only orthographic knowledge but also rhythmic synchronization was quite important for the development of Chinese reading in children with early grades in elementary schools.

The Effects of Folk Dance-Based Training on Children's Reading, Rhythm and Cognitive Abilities

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The well-established relationship between rhythmic abilities and reading skills has led to various training interventions aimed at enhancing literacy through music and rhythm-based activities. In this study, we investigated the effects of a dance-based training program incorporating folk dance elements on children's cognitive and reading-related skills. A total of 60 children participated, with half assigned to the training group and half to a control group. Participants were assessed on rhythmic abilities, reading skills, intelligence, and executive functions using the following measures: Beat-Based Advantage and Complex Beat Alignment tasks, the 3DM-H Dyslexia Differential Diagnosis Maastricht test (Hungarian version), Raven's Coloured Progressive Matrices, the Digit Span subtest of the WISC-IV, Verbal Fluency, and the Numerical Stroop task. The dance training was conducted twice a week and was based on the "táncház" method, incorporating traditional dance motifs performed with live zither accompaniment, as well as folk games involving singing and movement. The program was designed to align with the children's age-specific musical and motor development, employing a comprehensive pedagogical approach that integrated active vocalization, verbalization, movement, and passive auditory exposure to instrumental music. Preliminary results indicate that, while both groups showed improvements over time, the training group exhibited mild advantages in executive function measures by the end of the intervention. These findings contribute to the growing body of research on the role of rhythm-based training in cognitive, rhythmic and reading development of children.

Music is multimodal: introducing a multi-data corpus of music and dance performance

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Real-world experience of music often entails inputs coming concurrently from different sensory modalities beyond audition, such as vision (e.g. watching musicians or audience members moving or dancing). This multimodal context might thus critically contribute to music perception and behavior as experienced over the course of life. Relatedly, there is increasing experimental evidence that vision influences the perception of musical features such as duration (Schutz & Lipscomb, 2007) and tempo (London et al., 2016) as well as other dimensions including expressivity (Vuoskoski et al., 2016) and emotion (Lange et al., 2022). Yet, in cognitive (neuro)science, music is usually regarded mainly as an acoustic phenomenon or a psychological construct in response to an acoustic input. Moreover, notwithstanding major technical and conceptual advances in optimizing ecological validity, laboratory settings still arguably offer a narrow window into musical behavior. The current paper aims to bridge this gap by introducing the collection, curation, structure, and contents of a set of real-world music and dance performance recordings from Mali (West Africa). The corpus features an unprecedented breadth and depth of multimodal data. Specifically, it consists of 10+ hours of ethnographically documented multi-data (multi-track audio, two-camera video, and full body motion capture data) from three drum ensembles, four dancers, and 20+ different pieces, capturing music and dance performers as well as participatory audience members in multiple takes of each piece. Based on this comprehensive design, the corpus is expected to provide new insights on a number of phenomena, including rhythm and other musical features, but also multi-sensory integration, embodied cognition, ensemble coordination and entrainment, and cross-cultural variation. Together, this corpus thus bears the potential to inform on human musical behavior with an enhanced ecological validity.

The musical beat is multimodal

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Music cognition research generally assumes the perception of musical beat to occur in response to an acoustic signal and hence usually focuses on auditory stimuli. However, in real-world musical interactions, the beat is arguably often experienced through multiple sensory modalities beyond audition, such as vision. Moreover, experimental studies have provided evidence for cross-modal processing of temporal features such as duration (Schutz & Lipscomb, 2007) and tempo (London et al., 2016), and for the embodied nature of beat perception as co-cued by both music and dance (Naveda & Leman, 2009; Naveda et al., 2016; Toiviainen & Carlson, 2022; Toiviainen et al., 2010). Here, we move a critical step forward in this multimodal account of the musical beat by showing that senses other than audition, specifically vision, may play a key role in its perception and learning. To this aim, we capitalize on data from a novel corpus, including full-body 3D motion capture data of dancers and multi-track audio data of musicians recorded in the real-world context of music and dance performance in Mali (West Africa). We extracted rhythmic cue time points in both modalities (trajectory endpoints in dance movement and acoustic event onsets in the music) and conducted both time-domain and frequency-domain periodicity analyses. We show that the beat periodicity is embodied in the dance in a way that is complementary to the music rather than systematically redundant. In particular, when the beat periodicity is not prominently conveyed by the music, the dance, in contrast, does show it prominently. Together, these findings corroborate that the beat is not necessarily mapped directly from regularities in the acoustic signal, demonstrating its multimodal nature as experienced over the course of life. More generally, these observations favor a wholistic view of the musical beat as depending on multiple affordances for perceptual learning in real-world contexts.

The Influence of Rhythmic Cycle Length, Cultural Familiarity, and Musicianship on the Perception of North Indian Rhythmic Patterns

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Most studies on cross-cultural rhythm perception focus on shorter-cycled Isochronous (ISO, regular beats) and Non-isochronous (NI, unequal subdivisions of beats) meters. Long rhythmic cycles in North Indian Classical Music (NICM), which can be both ISO and NI (Clayton, 2020), suggest an impact of length on their perception. The 'effect of length' has been explored for musical tones and words (AkivaKabiri et al., 2009). Current study explores this effect in long rhythmic cycles of NICM. It aims to study: 1. Effect of length of rhythmic cycle and learning among varying musicianship and cultural familiarity. 2. Interplay between cycle length and the ISO and NI nature of long rhythmic cycles. Stimuli: Four NICM rhythmic cycles/patterns ('Original'/ N). ISO: 8-beat-Kehervatal (4+4) and 16-beat-Teental (4+4+4+4); and NI: 7-beat-Rupaktal (3+2+2) and 10-beat-Jhaptal (2+3+2+3). Test stimuli include an altered pattern with an extra beat(N+1). Participants: 81-Culturally Familiar (Indian) Non-Musicians, 65-Culturally Unfamiliar (western) Musicians, and 61-Culturally Unfamiliar (western) Non-Musicians. 3-part Task: 1. Base-Learning-Condition, 2. Training/short-term learning, and 3. Test-Learning-Condition. Base and Test Learning-Conditions involved participants rating stimuli compared to the original on 7-point Similarity scale ('Extremely-Similar' to 'Not-at-all-Similar'). Training included instructional pattern video and practice. Results: Familiarity and musicianship both affect the recognition of rhythmic patterns uniquely. Culturally-Familiar-Non-Musicians and Culturally-Unfamiliar-Musicians learned shorter rhythmic cycles, and longer rhythmic cycles posed challenges, suggesting an effect of length. Culturally-Unfamiliar-Non-musicians showed no learning. This effect of length was influenced by NI nature, as Culturally-Unfamiliar-Musicians differentiated 10-beat-Jhaptal in Base-Learning-Condition.

References

Akiva-Kabiri, L., Vecchi, T., Granot, R., Basso, D., & Schön, D.(2009). Memory for tonal pitches: A musiclength effect hypothesis. Annals of the New York Academy of Sciences, 1169(1), 266-269.

Clayton, M.(2020). Theory and practice of long-form non-isochronous meters: The case of the North Indian rüpak tāl. Music Theory Online, 26(1).

15:35–17:05. Session 6: Social & Interpersonal Rhythm

Do Work Songs' Musical Features Reflect Their Role in Interpersonal Coordination?

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From sea shanties to oyster dredging songs, work songs have been credited with several functions, one of them being the facilitation of temporal coordination in collaborative tasks. This provides reason to expect that features which support temporal coordination should be more prevalent in work songs than in non-work songs. For example, we reasoned that call-and-response patterns, in which solo parts stabilize the tempo, and the chorus synchronizes efforts, should be particularly prevalent in work songs. To test this, we worked with the Cantometrics database, which includes over 5,500 songs, 310 of which are classified as work songs. In Phase 1, we preregistered hypotheses based on variables that are already coded in the database, such as rhythmic complexity, inter-part rhythmic relationships, tempo, rubato, and vocal group organization. Since the database includes information on the societies the songs originate from, we can incorporate culture as a potentially important factor in our analysis. As predicted, the results confirm that work songs exhibit features which support temporal coordination. For example, even after controlling for culture, work songs were indeed more likely than non-work songs to follow a call-and-response pattern. In Phase 2, we will code variables related to relevant parameters of the tasks these work songs accompany. These parameters include coordination demands, rhythmicity, and physical effort involved in those tasks. This enables us to probe further links between task parameters and the rhythmic characteristics of work songs These findings support a connection between musical features and the coordination function of work songs. By expanding the coded variables for work songs in the Cantometrics database, this study will also enable more fine-grained analyses of task-specific rhythmic adaptations, such as asymmetric meters in oyster dredging songs.

When is it harder for musicians to resist entrainment?

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Contemporary Western art music is replete with works in which performers must resist falling into synchrony with one another, either because they are engaged in "phasing" (Schutz, 2019) or they have to perform a complex polyrhythm (Poudrier, 2013). Such processes might be more or less difficult to achieve as different unintentional synchronization mechanisms (e.g., phase correction, phase or anti-phase attraction, entrainment) become more or less salient depending on the rhythmical and group organization. To explore this issue, a group of six professional musicians, with a high expertise in performing collectively complex rhythmical behaviors, were asked to participate in two studies. Study 1 explored how various tempi relationships within the group impact the musicians' ability to resist synchronizing with one another. The six musicians had to play together, with each musician receiving an individual tempo at the beginning of each trial, according to four conditions: same tempi (80 bpm); low complexity polyrhythm (2:3:4:6:8:12); high complexity polyrhythm (3:5:7:11:13:17); close tempi (75, 77, 79, 81, 83, and 85 bpm). In half of the trials, musicians could rely on a click track. Study 2 assessed group size effects in resisting entrainment. Musicians were individually asked to tap at 120 bpm while seated in front of either one or three musicians –tasked with tapping at 126 bpm. In half of the trials, they could rely on a click track. This overall experimental design allowed us to contrast the musicians' rhythmical behaviors in an ecological setting (strong coupling between the musicians) and an artificial one (low coupling because of the click track). Our main dependent variables are mean inter-onset interval and coefficient of variance. Analyses are still underway but results will be interpreted in light of theoretical frameworks on sensorimotor synchronization (Repp, 2012), dynamical systems (Large et al., 2023) and flexible synchrony (Gordon et al., 2024).

Individuality and collectivity in professional orchestra string sections: Gauging the strength of coordination in body motion

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Most research on expressive rhythmic coordination in music-making has focused on small group interaction (e.g., duos or quartets). The conditions for coordination are different in large groups like orchestras, where the organization of players is more hierarchical and there is less opportunity for direct interaction between individuals. This study addresses the question of how closely orchestral string musicians coordinate their expressive body motion. String players are of interest in this respect because they mostly play in unison with others in their section and, with their section, must produce a synchronized, blended sound. We collected data from musicians in two professional classical orchestras during dress rehearsal and live concert performances. This study focused on their performances of Harald Sæverud's Kjempeviseslåtten (n = 14 concert performances + 3 dress rehearsals). The analysis used data from string musicians who wore accelerometers on their back that captured motion of the body core. A subset of musicians in one of the orchestras also wore accelerometers on their bowing wrist. The study aimed to contextualize how coordinated the string sections were in their body core and bowing wrist motion by, first, comparing the strength of coordination with how consistent the individual musicians were in their motion across repeat performances, and second, by showing how the strength of coordination changed in relation to music structure. Results show that within-player consistency was significantly greater than within-section coordination, for both body core and bowing arm motion, indicating that string musicians are highly consistent and individualized in their motion styles. The musicians coordinated less strongly at certain phrase boundaries and at moments where the music increased in intensity. These results show that there is room for individual expressive styles in professional orchestral performance, and that expressivity is most individualized at points of musical transition.

Respiratory timing in orchestral performance

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Breathing is a necessary physiological function during music performance, and the timing of respiration by wind players and singers are reliable constrained by their performance actions. The relevance of respiration timing to other instrumentalists and across large ensembles has not be investigated in detail. One study on solo pianists found little reliability, while many studies of string quartets and other chamber groups often have not bother to monitor performers' breathing. The Bodies in Concert experiments measured orchestral musicians breathing, cardiac activity, and motion during repeated performances in three concert series. Looking closely at the timing of respiratory sequences captured for a set of annotated pieces (6 pieces, 5-8 performances, 30 - 55 musicians per ensemble), we consider specifically the coincidence of inspiration and expiration onsets between performers in each section of the orchestra and within performers between performances with audio-based dynamic time warping. These orchestral musicians' breathing show consistent timing beyond the most expected cases. Performers varied in their intra-performance reliability, averaging 20-50% consistency while playing (depending on the section) and 10-15% while tacet. Between players, expiration onset coincidence rates were also significantly higher that chance or alternative conditions for all string sections as well as brass and winds. Patterns within string sections over repeated performances highlight passages for which these players reliably recruit their respiratory system. However, these moments do not appear sufficient to fully explain the exceptional degree of respiratory coordination measured in each performance. The respiratory patterns captured show substantial disruptions allowing alignment with musical action rather than coincidental phasing between steady oscillatory systems, even in non winds. For many of these musicians, breathing looks to be an important if not always essential component of precise musical performance.

Entrained in musical games: multimodal communication and flow

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Playground musical games can be a way for children of 6-12 years old to fill their 'empty' time when not under strict adult supervision, such as during school breaks and in assembly lines (cf Marsh, 2008; Saltari & Welch, 2022). Musical games are social, as two or more players are needed; they are also multimodal, because players use multiple ways of communication that is verbal as well as non-verbal (i.e., gestures, gaze, facial expressions and body movements). Collaboration between players in musical games becomes possible through image-and-text mirroring. In a recent study on children's playground musical games (Saltari & Welch, 2023), a multimodal analysis was applied to acquire a deeper understanding of the sources and processes by which meaning was internalised and negotiated. A key finding in this study was that players' entrainment ensured the flow of the performances despite occasional perturbations, such as a player performing linguistic and bodily patterns that differed from those of their partner's, or lagging by seconds or even milliseconds. Players made adjustments during performance so that they continued to be in synchrony and complete the musical games successfully. It is derived that musical games' sonic, rhythmic, and linguistic features allow individuals to be part of a structure achieving entrainment. A relevant study (Tunçgenç & Cohen, 2016) reported that synchronised movements in physical play affect pro-social behaviour. Further exploration on musical games is needed to gain a deeper understanding of entrainment as an element that fosters players' reciprocity and enhances possible social bonding.

The effect of temporal complexity and sensory modality on self-other representations in dyadic rhythm production

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Earlier research shows that moving synchronously with others promotes social affiliation. Indeed, simultaneous movements to a perceived regular musical beat emerge naturalistically in group musical interactions. However, individuals often also produce rhythmic variation when producing music together. The Music and Social Bonding hypothesis posits that such interpersonal rhythmic variation could also be conducive to social bonding, possibly due to a metrical hierarchy acting as a temporal scaffold for balancing individual expression through clearer self-other distinctions while maintaining group contributions. Testing this idea is challenging, because producing complex rhythms with others requires high expertise. We designed a dyadic drumming task that combined metronomes and background music with visual cues to aid complex musical rhythm production in the general population. We manipulated temporal complexity on three levels: identical (e.g., 2:2), integer multiples (e.g., 2:6), and polyrhythms (i.e., ratios with no common divisors, e.g., 2:3). As participants produced these rhythms, we recorded their drum timing and asked for ratings of social connectedness to the other on the continuous IOS scale ("Inclusion of the Other in the Self"). We considered these ratings to reflect the extent to which psychological self-other representations are merged. To tease apart the effect of multiple task-relevant sensory modalities on self-other merging, we also manipulated audio feedback and device-sharing in three conditions: only self audio - separate devices, bidirectional audio - separate devices, and bidirectional audio - shared device. According to the hypothesis that meter affects self-other merging, we predict that increased temporal complexity would lead to 1) decreased IOS ratings , and 2) larger effects of multimodal sensory information exchange on increases in IOS. This would suggest that self-other representations become more segregated and demand greater sensory exchange as complexity increases. The presentation will discuss results from a currently ongoing data collection.

Day 3: Wednesday 18th

9:00–10:00. Keynote: Anna Fiveash

Predicting "what" and "when" in music and speech: Effects of musical training, task, and domain

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KL

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Prediction is a fundamental aspect of cognition that allows us to anticipate what is about to occur, and when it will happen. However, little is known about how these two types of predictions interact, whether they operate differently across stimulus domains such as music and speech, or the influence of the experimental task. These questions were investigated across a series of studies, where content and timing predictability were comparably manipulated within melodies and sentences to investigate effects on perception of content, perception of timing, and production. In Experiment 1, participants judged the content of melodies and sentences (completion ratings). In Experiment 2, participants judged the timing of melodies and sentences (timing judgements). In Experiment 3, participants sang or spoke the note or word they expected to complete the melody or sentence (melodic/linguistic cloze probability task), to directly investigate developing predictions. In Experiments 1 and 2, musician and non-musician groups were recruited to investigate effects of music training on perception across domains. Results revealed differences depending on domain and musical training, as well as the task. Taken together, the results suggest that content and timing predictions affect music and speech differently, perhaps depending on the relative importance of these cues for each domain. Further, musical training appears to enhance predictive capacities not only in music, but also in speech processing. These findings will be discussed as part of a larger framework with the aim to understand different types of prediction in the brain, different effects of task, and the cross-domain influence of expertise.

10:20–11:50. Session 7: Neural 2

4/4 and Even More: Pupillometry, Groove, and Uncommon Meters Galore

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In music psychology, groove is defined as the pleasurable urge to move to music. Previous work has found that rhythmic complexity exhibits an inverted U-shaped relationship with this experience. Physiologically, sustained pupil dilations (a measure of noradrenergic attention allocation) have been found to exhibit a similar relationship while entrained pupillary activity (an index of attentional precision in time) has been shown to decrease with increasing rhythmic complexity (Spiech et al., 2024). Previous work (Spiech et al., in revision) has found that groove's relationship to rhythmic complexity is modulated by metric expectations: rhythmically simpler music samples elicited higher groove ratings when the music was in uncommon meters (e.g., 7/8) as opposed to common ones (i.e., 4/4). These results imply that the listener's metric model impacts rhythm processing in groove, but it is unclear whether attention is similarly affected by these metric models. Specifically, the deployment of metric models was hypothesized to demand greater attentional resources (as evidenced by greater sustained pupil dilations) and result in better rhythmic processing (as evidenced by pupillary entrainment). Thus, we recorded participants' pupil sizes while they listened to 26 musical clips in either 4/4 or an uncommon meter. Following each clip, participants rated how much the music made them want to move and how much they liked it. Behavioral findings replicate prior work, with ratings in common meters following the inverted U-shaped pattern whereas for uncommon meters, lower rhythmic complexity elicited the highest level of groove. Preliminary sustained pupil dilation results show no difference by meter, indicating comparable attention allocation. Similarly, the pupillary entrainment is stronger for rhythmically simple music regardless of the meter and as rhythmic complexity increases, attentional entrainment switches from the beat to the slower, more predictable bar level. These findings suggest that attentional processes in groove are not sensitive to metric expectations.

Groove and rhythmic complexity modulate internal motor simulation in response to music

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Theoretical accounts of rhythm cognition propose that internal motor simulation helps the brain predict the timing of beats and rhythmic patterns. One potential neural index for internal motor simulation is suppression of mu- and beta power over the sensorimotor regions, previously associated with motor imagery and the observation of movements. We investigated mu- and beta-power over the sensorimotor regions in response to music stimuli systematically varying in rhythmic complexity and groove, compared to random rhythms. If internal motor simulation is involved in the prediction of upcoming beats, beat-based stimuli should evoke more mu- and beta-suppression in comparison to random rhythms. Furthermore, groove, rhythmic complexity, and trait empathy should also modulate the degree of suppression. Participants (40 adults) heard 5 different versions (low, medium, high, and very high rhythmic complexity, and random) of 3 rhythm patterns with drums, keyboard and bass (all 120 BPM). After each of the 15 excerpts, participants rated their experience of groove, the ease of perceiving a beat, and enjoyment. 64-electrode EEG (BioSemi ActiveTwo) was recorded, and the Interpersonal Reactivity Index (Davis, 1980) was used to measure trait empathy. Average mu- and beta-power over the sensorimotor regions in each rhythmic complexity condition were converted into log-transformed power ratios relative to the random rhythm condition. One-sample t-tests revealed significant suppression (relative to random rhythms) in the medium (mu & beta) and high (beta) complexity conditions. Linear mixed-effects modelling further revealed that groove ratings were significantly associated with both mu- and beta-suppression, and affective trait empathy significantly modulated average power in the low (mu), medium (mu & beta), and high complexity (mu) conditions. The results suggest that beat-based music and groove may indeed evoke internal motor simulation. Trait empathy interacted with rhythmic complexity in predicting average mu- and beta-power, suggesting that social-cognitive capacities may also contribute to rhythm processing.

Frequency-Resolved Brain Network Estimation via Source Separation (FREQ-NESS)

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The human brain operates as a dynamic network system where neural rhythms serve as a fundamental organizing principle, structuring interactions within and across spatial and temporal scales. These endogenous rhythms also interact with rhythmic sensory input, regulating perception and cognition. To disentangle simultaneous rhythmic brain processes and their neural underpinnings, we introduce FREQuency-resolved brain Network Estimation via Source Separation (FREQ-NESS), a novel framework for estimating brain networks operating at specific frequencies. In this study, we applied FREQ-NESS to source-reconstructed MEG data recorded during resting state and rhythmic auditory stimulation to characterize the brain's organization at rest in a landscape of frequency-specific networks. We then compared this landscape to that produced by passive listening to isochronous auditory stimulation at 2.4 Hz, aiming to detect changes in its spatiotemporal organization. Resting-state results revealed a frequency-resolved characterization consistent with canonical networks previously reported in the literature, including the default mode network (DMN), multiple alpha networks, and motor beta networks. Notably, auditory stimulation led to the following local changes in the brain network landscape: (1) the emergence of auditory networks attuned to the stimulation frequency, (2) a shift of alpha-band networks toward higher frequencies, accompanied by a spatial reorganization from occipital to sensorimotor regions, and (3) enhanced cross-frequency coupling between low-frequency auditory networks and gamma-band activity in medial temporal regions. Networks irrelevant to the passive auditory task, such as beta motor networks, remained stable across conditions. By revealing how brain networks dynamically reorganize across frequencies in response to rhythmic stimulation, FREQ-NESS provides a robust tool for exploring neural processing in both fundamental and applied neuroscience. Future studies can leverage this framework to investigate how frequency-specific interactions support cognition, perception, and neuroplasticity, as well as to assess alterations in brain dynamics associated with clinical conditions.

Neurofeedback-Driven AI for Adaptive Rhythmic Interactions

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Rhythmic synchronisation is a complex, cross-cultural phenomenon with applications in both entertainment and healthcare. Improving the user experience of these interactions can enhance emotional and health benefits for participants, highlighting their relevance. However, in human-computer interactions, previous research has shown that people experience significantly less excitement (arousal) when interacting with a fixed rhythm compared to another person. As emotional experience is paramount, the computer needs to exhibit human-like adaptability to better mimic human-human interaction. In addition, a deeper understanding of the user experience could further enhance the interaction. This reasoning led to the development of a synchronisation paradigm in which participants performed with either a human or one of two AI models capable of adapting to human tempo variations. Participants synchronised their tapping to either a human partner, an AI model or an EEG-based AI model. The latter model used user-experience related biomarkers to assess and improve interaction quality. The study investigated user experience and the impact of EEG-informed control on both simple (waltz, march) and complex (polyrhythmic) rhythms. The presented research details initial findings on human-human and human-AI interaction, the impact of EEG-based modulation on self-reported experience, and future research directions.

How our brains process speech in noise: does rhythmic regularity enhance comprehension?

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Comprehending novel information in noisy everyday life is difficult. Compared to speech, hearing information as song might be beneficial due to song's rhythmic predictability and because song can be more closely processed –neurally tracked –by the brain. However, such neural tracking has not yet been compared to behavioural outcomes (e.g., comprehension), limiting our understanding of how the brain parses complex signals into meaningful information. The current study assessed (1) whether comprehension of novel information is better when it is sung than spoken due to (2) greater rhythmic predictability and (3) stronger neural tracking. In our preregistered study, we recorded electroencephalography (EEG) from 36 participants (based on a G*Power analysis) listening to naturalistic spoken and sung stories. We confirmed songs had lower inter-onset interval entropy (higher rhythmic predictability) than speech ($p = .033$). Additionally, stimuli were presented on their own (clear condition) or embedded in multi-speaker babble noise at 5 or 1 signal-to-noise ratio (SNR). Neural tracking was estimated using forward temporal response function (TRF) analyses. While (1) comprehension was comparable between speech and song in clear conditions, comprehension was significantly better for song in difficult listening conditions (1 SNR, Bonferroni-corrected $p < .001$). Comprehension was not, however, (2) significantly correlated with rhythmic predictability ($p = .878$). EEG data are still undergoing preprocessing, but preliminary neural results show (3) stronger neural tracking (i.e., higher P1-N1 TRF amplitude) in song at 1 SNR ($p = .035$). Together, we show that in noisy conditions, information in song has better comprehension and stronger neural tracking. To assess generalisability of our findings, we are currently running a similar study using mobile EEG in a more naturalistic (classroom) setting. Overall, we show song can be used to enhance comprehension, which could have educational applications, especially for those with learning difficulties.

A sweet spot at 2 Hz for auditory perception in noise

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Isochronous stimulus delivery benefits neural encoding and behavioural performance, possibly because the resulting rhythmic stimulation aligns with the frequency of active neural oscillators. Entrained oscillatory activity resists Gaussian-distributed temporal jitter in stimulus onset. We tested the effects of uniformly distributed noise as human participants detected unpredictable pitch changes in pure tone sequences (Roving standard paradigm). The mean duration of stimulus onset asynchrony was parametrically varied to cover the delta band (250 ms = 4 Hz, 500 ms = 2 Hz, and 1000 ms = 1 Hz). The amount of uniform jitter in stimulus onset also varied: isochrnous stimulation, 10% jitter, and 30% jitter. We found that maximal temporal noise at 2 Hz significantly increased both behavioral performance and neural encoding as measured via EEG (Mutual Information), while concurrently reducing them for both faster and slower rhythms. Perception at 2 Hz may tap into a dynamic prior or attractor which incorporates significant temporal noise.

14:15–15:15. Session 8: Microtiming

Just Noticeable Difference Thresholds of Musical Microrhythm (Asynchrony and Non-isochrony) in Multi-Instrumental Groove-based Performance

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Musicians can convey different 'timing feels' in performance by manipulating asynchronies between instrument onsets ('behind'/'ahead'/'on-beat') as well as the degree of non-isochrony within metrical subdivisions ('straight'/'swung'). The extent to which we can perceive such microtiming nuances has only yet been examined in non-/quasi-rhythmic contexts involving monotonic and single-layered stimuli, with mixed results regarding effect of musicianship. Studies have also found that pupil size increases linearly with asynchrony magnitude, but not yet examined non-isochrony. We measured the just noticeable difference (JND) thresholds of asynchrony (Exp. 1) and non-isochrony (Exp. 2) in a naturalistic, multi-layered groove (funk pattern, IOI $\approx$ 143ms) with 5 instruments (guitar/bass/kick/snare/hi-hat). Using a 1IFC staircase and global displacements of individual instrument layers (asynchrony: $\pm$1-100ms [early/late], non-isochrony: +1-71.5ms [late]), we tasked participants (N=64; musicians N=32; non-musicians N=32) to determine whether instruments were playing; "together" with or "before/after" other instruments (Exp. 1); and with "straight/even" or "swung/uneven" rhythm (Exp. 2). Pupil response was also measured. As expected, JND thresholds were higher than reported in previous literature (+4%/+2% of IOI for asynchrony and non-isochrony, respectively) likely due to greater attentional 'noise' from additional simultaneously playing instruments, and lower for for musicians (14%/16%) than for non-musicians (22%/24%) due to greater training in the perception/production of musical microrhythm. For the first time, we also demonstrate an effect of both Instrument and Timing displacement, where onset displacements were harder to detect: in string (22%/24%) rather than drum (15%/18%) instruments - likely due to perceptually 'fuzzier' acoustic attack profiles; and in late (20%) rather than early (16%) displacements - likely due to forward acoustic masking effects. We also found a linear relationship between pupil size and both asynchrony and non-isochrony, further indicating that the pupil indexes mental effort in auditory processing of microrhythm more generally.

Timing and dynamics of the Rosanna shuffle

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The Rosanna shuffle, played by Jeff Porcaro on Toto's 1982 hit Rosanna, is one of the most recognized and influential drum grooves in popular music. This intricate half-time shuffle is characterized by a nuanced interplay between the hi-hat, snare, and ghost notes, producing a distinctive rhythmic texture. In this study, we conduct a detailed analysis of its timing and dynamic variations, focusing on swing feel, microtiming deviations, tempo fluctuations, and the structural role of the hi-hat pattern. Our findings reveal that the shuffle exhibits a pronounced swing feel, which is unusually strong for a rock/pop context and contributes to its unique groove. Through microtiming analysis, we identify long-range correlations in timing deviations, reinforcing the organic nature of Porcaro's performance. Additionally, tempo drift is present throughout the track, reflecting the natural fluctuations of a performance recorded without a metronome. We further analyze these deviations using stochastic modeling to better understand the underlying rhythmic tendencies. A key characteristic of the groove is the two-bar phrasing structure, where subtle variations in hi-hat dynamics shape the rhythmic flow and enhance musical phrasing. This dynamic interplay between timing and articulation strengthens the track's groove, making it feel fluid yet precise. Our analysis underscores the Rosanna shuffle not only as a technical achievement in drumming but also as an example of rhythmic complexity in popular music.

Perceptual timing precision for complex sounds improves with similarity to preceding sound context

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Temporal regularities play a crucial role in auditory processing by providing predictive cues about upcoming auditory inputs: Perceptual sensitivity for on-beat events is increased while off-beat occurrences can bear important information, e.g., in music and speech. Effective use of such temporal information hinges on the precision with which onset timing of single events, and their deviation from preceding temporal structures can be evaluated (perceptual timing precision). Recent work suggests that perceptual timing is less precise for complex sounds, e.g., music or speech, than for simple sounds, e.g., clicks. The underlying assumption of this work is that perceptual onset timing and precision solely depend on sound acoustics and are independent of preceding sound context. Consequently, perceptual timing has mostly been evaluated in simple sound beat contexts. Here, we challenge this assumption and hypothesize that acoustic similarity between context and target might enhance perceptual timing precision, independently of sound complexity. To test this, in a 2x2 within-subject design, participants (n=21) iteratively adjusted the timing of a target sound (click or complex harmonic tone) relative to an isochronous cueing sequence consisting of four identical sounds (also either click or complex harmonic tones) until perceptual isochrony was reached. In line with prior reports, we found reduced perceptual timing precision for complex versus simple sound targets. Critically, as hypothesized, complex sound contexts reduced perceptual timing precision for simple but not for complex targets. Rather, perceptual timing precision for complex targets was improved when preceded by complex sound cues. Overall, our results show that similarity between acoustic context and targets establishes a high-precision beat percept, enabling fine-grained analysis of target onset timing. This enhances the perceptual ability to rely on temporal information when processing complex auditory streams such as music or speech.

Where is the Beat in that Complex Note? Effects of Instrument Asynchrony and Attack on the Perceived Timing of Compound Musical Sounds

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In musical ensembles most notes/chords are sounded by more than one instrument at the same time, and we hear them as simultaneous, even when their onsets are not precisely simultaneous. Here we obtain estimates for the perceptual centers of such compound sounds when there are microtiming asynchronies between the instruments. In Exp1 three combinations of fast-attack instruments (acoustic kick drum/synthetic kick, kick/hi-hat, kick/bass) were presented with five levels of instrument asynchrony relative to the kick (-40, -20, 0, 20, and 40 ms); the ISI was 600ms (100 bpm) and the task was to align a click with the compound sound. An RMANOVA shows main effects ($p<.001$) of Asynchrony and Instrument combination, and a U-shaped relationship between Asynchrony and P-center, such that asynchrony in both directions relative to the kick (kick early and kick late) delays the P-center for the compound sound. In Exp2 we used combinations of fast and slow attack instruments. Ten combinations (three fast-attack–fast-attack, three slow-attack–slow-attack, four fast-attack–slow-attack) were presented with seven levels of instrument asynchrony: -80, -40, -20, 0, 20, 40, 80. RMANOVAs of the results revealed different relationships between asynchrony and P-center ($p<.001$): Fast/fast attack combinations replicated the U-shape of experiment 1. In fast/slow combinations, the P-center followed the fast-attack instrument linearly, and in the slow/slow combinations, P-centers followed the higher-pitched instrument. P-centers of compound sounds depend on both the asynchrony between the instruments and the shape of their attacks. Combinations of fast-attack instruments with extreme asynchrony produce bimodal distributions, indicating perceptual segregation of the two sounds. The findings align with studies showing that sharp sounds are used as landmarks for segmentation and timing in speech and music.

15:35–16:50. Session 9: Groove

Instant Groove & sustained Catchiness: exploring differences between Groove and Catchiness through temporal thresholds

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Background: Over a series of studies, we have found a positive relationship between groove (as urge to move) and catchiness. In this study, we examine its limits: when are groove and catchiness not related? We focus on temporal thresholds: groove is thought to require representation of meter and repetition, and thus a certain duration, while catchiness is thought to act within fractures of a second. Hence, we expect very short music to promote catchiness but not urge to move. Methods: We use 54 AI generated popular music excerpts of 9 different styles in two tempos, either lasting 1 or 10 seconds. In the 1s condition, the fast stimuli encompass 2 beats, and the slow stimuli encompass 1.5 beats. In an online listening experiment, participants rated the stimuli on urge to move and catchiness. Results: We found a correlation between urge to move and catchiness in the 1s condition (r = 0.402), which is weaker than in the 10s condition (r = 0.487). Ratings in 1s and 10s conditions are correlated for urge to move (r = 0.548) and catchiness (r = 0.432). Urge to move is lower in 1s condition compared to the 10s condition (BF > 1000), while there is no difference for catchiness. The 1s stimuli at fast tempo/2 beats are rated higher for urge to move than at slow tempo/1.5 beats (BF > 1000), while catchiness remains unaffected by tempo. Conclusion: Our study shows that groove and catchiness are correlated in very short stimuli –potentially linked causally. Surprisingly, there is an instantaneous urge to move - faster than a common bar or pattern, with just a hint of regularity –which is indicative of a more sustained experience. We confirmed that catchiness is perceived immediately but found that it is not necessarily sustained over time.

The effects of "feeling moved" and "groove" on standstill

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Music makes us move, even when we try to stand still. The standstill paradigm has been used in previous research to show that even when participants try to stand still, music makes us move more than silence and certain musical genres and features evoke more involuntary motion than others. We used the standstill paradigm to explore how micromotion is affected by groove-based music and its rhythmic structures, familiarity, and emotionally moving music. We also examined whether task success or more motion is associated with social connectedness. We found that groove elicited more micromotion, though familiarity did not have an effect. Music evoked more micromotion than silence in all directions. However, song excerpts did not evoke more micromotion than drums except for in the mediolateral plane (sideways). Pulse clarity and tempo were positively associated with micromotion. Feeling moved was associated with less motion in the mediolateral plane than a matched control, therefore the results do not explain the passive voice linguistic labels of this emotion (i.e., "feeling" or "being" moved). Perceived group success was related to feelings of social connectedness. Together, these results contribute to further understanding of the embodied nature of music cognition and suggest that music has complex effects on involuntary micromotion. Nonetheless, these results suggest that groovy music has an uncontrollable power over our bodies.

The Role of Expressive vs Mechanical Music Performance in the Relationship Between Pleasure and Wanting to Move: A Behavioral and Pupillometry Study

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Rhythm is a core feature of music that drives pleasurable responses, including through its coupling with sensory-motor processes. Groove, the pleasurable urge to move to music, is universally experienced and peaks with rhythms of medium complexity, which optimally balance predictability and surprise. However, while performance features like tempo, timing, dynamics, and articulation enhance music's emotional impact, their role in shaping pleasure and wanting to move remains unclear. Our ongoing study investigates how expressive versus mechanical piano performances influence the relationship between pleasure and wanting to move. In Experiment 1, adult non-musicians (expected N=60) will listen to 60 unfamiliar piano excerpts (30 a priori high-groove and 30 a priori low-groove stimuli), each performed mechanically and expressively, balanced for tempo (BPM) and style. Participants will rate felt pleasure, wanting to move, and perceived rhythmic complexity after each excerpt. We expect higher pleasure, wanting to move, and rhythmic complexity ratings for high- vs. low-groove stimuli. Additionally, we hypothesize that expressive performance–due to microstructural variations–will increase pleasure ratings in comparison to mechanical versions, particularly for low-groove excerpts, and similarly for wanting to move and complexity. In Experiment 2, a separate sample (N=30) will listen to the same excerpts while pupillometric responses are recorded and will complete the same task. We predict greater pupil dilation (previously associated with heightened pleasure, grooviness, and attention) for high- versus low-groove stimuli, as well as larger dilation for expressive stimuli compared to mechanical versions, particularly for low-groove excerpts. Eye-tracking allows for the indirect exploration of physiological connections between the eyes and the nervous system, providing moment-by-moment knowledge of ongoing non-conscious cognition processes in the visual domain as well as in the auditory one. Our study will provide new insights into the cognitive and physiological processes underlying groove, advancing our understanding of how music evokes pleasure and movement.

Dancing to music (is) like a hurricane: groove as stabilization of rhythmic coordination by body movement

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Music with an intermediate level of syncopation elicits the pleasurable urge to move, commonly referred to as groove, and elevates motor excitability at the downbeat. According to predictive coding theories, we move our body to syncopated rhythm to resolve prediction errors. Here we present an explanation of groove from a new theory of music perception and action based on ecological psychology, radical embodiment and coordination dynamics. The new theory, called embodied dynamics of music (EDM), describes music perception (and performance) as movement coordination, a form of perceptually guided action, instead of encoding and processing of sensory information. EDM treats music as a dynamic behavioral pattern that spans the brain–body–environment boundaries and cuts through the perception–action divide. Like other forms of coordinated movement such as locomotion gaits and interlimb coordination, musical patterns are subject to the constraints of coordination dynamics and thus can exhibit dynamic behaviors such as multistability and phase transition through loss of stability. EDM characterizes musical rhythm as a coordinative structure consisting of multiple movements. Metrical (beat-based) rhythm is a mode of coordination in which discrete movements (corresponding to individual events) are embedded and timed within continuous rhythmic movements (beat/meter). Downbeat serves as a regular anchoring point at which movements are tightly coupled, thereby stabilizing the coordinative structure. Syncopation (emphasis on weak beat) acts as a destabilizing force, but overt body movement at downbeat can stabilize the currently engaged coordinative structure. Thus, groove can be characterized as stabilization of coordinative structure by body movement, which can be compared to other self-organizing dissipative systems maintained by constant inflow of matter and energy such as hurricanes and living organisms. We will demonstrate the key ideas with musical examples and dynamical models and discuss an experimental agenda for testing the predictions of EDM.

How rhythm, bass, and social movement combine to motivate group dancing at an electronic dance music concert

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Group dancing is a worldwide human behaviour and involves complex auditory signals, full body movement, and social interaction. Prior research suggests that musical factors (e.g. complex rhythms and loud bass) and social factors (e.g., the movements of nearby individuals) can enhance people's movement to music. But we do not fully understand how group movement dynamics unfold on the dancefloor and whether these musical and social factors combine or compete with one another in terms of driving dancers' movements. In this study, participants (n = 65) were audience members at an electronic dance music concert. During the concert we measured participants' head positions over time using motion capture and calculated movement speed from those data. The musicians systematically manipulated the rhythm of the kick drum across three levels (none, basic pulse, or complex rhythms) and also manipulated the bass intensity (high or low). Simultaneously, confederate audience members manipulated the social environment by moving with either relatively high or low movement energy at prescribed times. Preliminary results indicate that audience members' movement was affected by rhythm, bass, and social movement energy, and, interestingly, that these factors also interacted. For example, complex kick drum rhythms tended to elicit faster movements than a pulse, except when both bass and social movement energy were low. We are also analyzing the data to understand how the specific structure and complexity of the kick drum rhythms affected movement speed, and to determine the nature of the group movement dynamics. Overall, these data will help uncover how rhythm, bass, and social factors combine in real-world group dance to motivate group movement.

Day 4: Thursday 19th

9:00–10:00. Keynote: Erin Hannon

It takes a lifetime to build a dancer: The development of entrainment-related musical abilities

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Musical entrainment plays an undeniably fundamental role in some of the most ubiquitous and socially significant human musical behaviors such as dancing and group music making. Nevertheless, music and musical behaviors exhibit tremendous cultural diversity and variability in rhythmic structure, which may have important implications for understanding how and when during development listeners build the musical knowledge and skills that enable them to respond meaningfully to rhythm, beat, and meter within their specific cultural context. In this talk I will provide an overview of evidence for development of entrainment-related abilities. I will contrast the seemingly precocious perceptual abilities of young infants with the relatively protracted development of entrainment-related behaviors such as synchronized movement, as well as entrainment-related perceptual abilities such as rhythm discrimination/categorization and matching metronomes to music. I will highlight the gradual emergence of cross-cultural differences in rhythm perception and production between infancy and adulthood, and discuss the implications of enculturation for social and emotional aspects of rhythm and beat perception. In particular, I will discuss recent work from our lab and others examining the role of enculturation and development in the experience of musical groove or the pleasurable urge to move. To the extent that a listeners predictions or expectations drive experiences of musical groove and musical pleasure more broadly, it is critical to examine how those experiences do or do not interact with musical expertise and entrainment-related skills as they emerge during development.

10:20–11:20. Session 10: Rhythm in Clinical Populations

Rhythmicity, visual attention, and the distinction between speech and song in autism

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Child-directed song (CD-Song) is a naturalistic, appetitive activity for autistic toddlers (Lense & Camarata, 2020). CD-Song contains predictable temporal structure that scaffolds visual attention in nonautistic infants (Lense et al., 2022), relying on prediction mechanisms that vary in autism (Cannon et al., 2023; Fram et al., 2023; Vishne et al., 2021). In this study, we manipulate rhythmicity of CD-Song to investigate spatiotemporal attention in a naturalistic, developmentally relevant context. Autistic (n=57, 43 male) and nonautistic (n=35, 22 male) toddlers between 14 and 40 months old were eye-tracked while watching videos of caregivers speaking and singing to them, along with versions of the singing videos manipulated to alter their temporal predictability (mild/moderate jitter). We computed spatial inter-subject correlations (ISCs) for each participant's eye position and every other participant with the same diagnosis. We predicted ISC with stimulus type and diagnosis using mixed-effects linear regression, with Tukey HSD pairwise post-hoc tests. In both groups, ISCs were highest (i.e., more consistent visual attention dynamics) in unjittered song, followed by moderate jitter, and then by mild jitter and speech. Nonautistic toddlers had higher ISCs than their autistic peers; this gap was significant in moderate jitter (0.07, $p<.001$) and speech (0.05, $p<.001$) stimuli, but not in mild jitter (0.02, $p=.28$), and less so in unjittered song (0.03, $p=0.04$). Autistic toddlers had higher ISCs in mild jitter than speech (0.03, $p<.001$), but nonautistic toddlers did not (0.01, $p=.89$). Rhythmicity scaffolds consistent visual attention to CD-Song. Diagnostic gaps in consistency may reflect the relative importance of entrainment and novelty in orienting attention during communication, whereby autistic toddlers are more reliant on predictability and familiarity than nonautistic toddlers, which may tie to cognitive flexibility (Lage et al., 2024). Future analyses will investigate how specific features of stimuli, including beat timing and visual motion, influence consistency of visual attention.

Neural synchronization to music in insomnia patients

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Sleep is crucial for physical and mental well-being, yet sleep disorders are widespread in modern society. Many individuals turn to music to improve their sleep, and clinical studies have shown that music can positively affect sleep quality [1]. However, the mechanisms by which music facilitates sleep remain unclear. Here, we explore whether brain waves synchronized to the beat of music could aid sleep onset. As part of a randomized controlled trial, we recorded 30 minutes of resting-state electroencephalography in the lab before and after four weeks of music-listening intervention for sleep. We applied frequency-tagging to electroencephalographic recordings of participants with sleep-onset insomnia (N=60): half of them rested with music chosen from playlists offering different genres, and half of them rested without music. The beat of the music was calculated via finger tapping and stimuli spectrograms. Analyses on both recordings together showed frequency-tagged amplitudes related to the beat of the music, with stronger responses occurring in songs with a consistent beat. Neural amplitudes correlated with tapping consistency measures ($r=0.178$, $p<.001$) and track order ($r=-0.123$, $p=.018$), suggesting that they reflect beat stability and got smaller by the end of the session, probably indicating sleep onset [2]. However, no significant correlation appeared when we investigated the relationship between neural amplitudes and sleep measures accounting for all sleep stages averaged: N1, N2, N3, REM. The neural responses of the music-listening group reflected rhythm processing because they were weaker or absent in the no-music-listening group. No differences between the two recording sessions were detected. This study explores naturalistic music-based intervention in insomnia patients, offering valuable insights into how synchronizing to music might facilitate sleep. Further analyses using power spectral density and linear mixed models will complement this research.

References

1-Chen, et al. (2021). J. American Geriatrics Society, 69.
2-Sifuentes-Ortega, et al. (2022). Cerebral Cortex, 32.

Learning sensorimotor synchronization through reinforcement in neural networks

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The ability to synchronize movements to auditory rhythms, foundational to music making and dance, develops over the first 10 years of life. The pleasure that often comes with audiomotor synchronization suggests that synchronization learning is driven by a system of intrinsic reward. Here, we ask what systems of reward can scaffold robust development of synchronization. We explore possible answers to this question in a recurrent neural network model whose input is a series of metronomic cues delivered at a range of possible tempi, and whose output is a series of finger taps executed with a short delay. The network is trained through reinforcement learning according to four possible reinforcement schemes that incentivize synchrony between tap and metronome in different ways. We find that the most successful approach to training is to reward early taps more than late taps and to reinforce tempo-matching (interval imitation) in addition to tap/cue synchrony. When the trained agent is tested on temporally perturbed metronomes, it shows error correction closely resembling human performance, including an asymmetry in which late taps are corrected more than early taps. When cue timing jitter is included either in testing or in training, the trained agent shows a human-like tendency to tap earlier than the cues (a “negative mean asynchrony”). In the neural activity, we find activity patterns consistent with those recently observed in monkeys trained to synchronize using a similar reinforcement scheme. We also observe a neural analogue to subjective rhythmitization, the observed tendency to perceptually experience metronome clicks in groups of two. Our results suggest that intrinsic reinforcement for early action and imitation may be important for robust development of audiomotor synchronization in humans, and offer us a model system in which to further explore synchronization learning and its neural substrates.

The Effects of Group Interpersonal Synchrony on Young Autistic Adults in Work Environment: A Mixed Methods RCT Study

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Group interpersonal synchrony, the coordination of movements among group members, is a powerful force that consolidates human groups while promoting the ability to self-regulate and cooperate with others. Dance movement therapists use interventions in which participants share synchronous movement to enhance well-being and increase social skills among autistic individuals. However, there is very limited research on the emotional and social effects of synchronized interventions on autistic adults. This mixed methods RCT study examined the effects of movement-based synchronized group intervention on the prosocial behavior, social cohesion, and work-related stress of young autistic adults enrolled in an innovative occupational training course. An autism-friendly physical exercise program was designed with two versions: synchronized, where movements are done together, and non-synchronized, where movements are done individually. In addition, the study aimed to explore participants post-intervention experiences from their own personal perspectives. A randomized controlled trial was conducted with two intervention conditions: synchronous and non-synchronous. One-hour-long sessions took place once a week for six to seven weeks. Quantitative data of the outcome measures was collected during four program cycles (N=54), which included self-report questionnaires and behavioral tasks using a pre-post-follow-up design. Qualitative data was collected through post-intervention interviews with a subset of the participants (N=12). The quantitative results suggest that the synchronized intervention may be more effective than the non-synchronized intervention in enhancing cooperative behavior after 17 weeks and fostering social closeness with familiar peers. The qualitative analysis resulted in four intrapersonal and three interpersonal subthemes while portraying differences between participants' experiences in the two conditions. The integrated findings resulted in an expanded composite holistic model to better understand the contribution of synchronized group intervention specifically for autistic individuals. The results provide valuable knowledge for future design of movement-based interventions to support a more successful integration into social and stressful work environments.

13:30–14:30. Session 11: Developmental Rhythm

The influence of tempo on neural encoding of rhythmic hierarchy in neonates

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Perceiving time intervals and structure of rhythmic patterns are of fundamental developmental importance, for instance for language, music, and social skills. Rhythm experience starts very early, during the prenatal period of development with the auditory system becoming functional as young as 24-25 weeks gestational age. We have recently shown that the neural following of auditory rhythm develops progressively during the third trimester of gestation, and that importantly its emergence might be tempo dependent (Saadatmehr et al. 2024, J Neuroscience). In the current study, we further address the impact of tempo on neural following of the rhythmic structure comparing neural responses of newborns to those of adults in a high-density EEG study. Towards this, we used the same repeating 6-beat ambiguous rhythmic pattern at two tempi, with the beat frequency equal to 3.33 Hz and 6.66 Hz for slow and fast tempi, respectively. We found stronger neural synchronization at the faster frequency in neonates while adults exhibited stronger neural synchronization at the slower frequency. We conclude that tempo (cycle duration) affects the processing of the rhythmic hierarchy differently at early compared to adult stages of neurodevelopment, and that neural synchronization to slower periodicity improves with age. We are further studying the underlying neural oscillations of beat encoding through calculating beat-phase/high-frequency-power coupling across tempi and neurodevelopmental stages, based on our recent study showing beat regularities are encoded in bursts of alpha oscillation in the premature brain (Edalati et al. 2024, Developmental Science). These results will shed light on early neural capacities for coding temporal regularities and developmental differences in frequency-specific neural dynamics.

First steps: Casting a developmental lens on human dance

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Dancing is ubiquitous in human cultures across the globe. It is also developmentally precocious –most parents report their children begin to dance before their first birthday –usually earlier than their first words. This early emergence precedes a long maturational trajectory with broad individual differences. The universality and precociousness have motivated a recent uptick in studies of dance and related behaviors (e.g., sensorimotor synchronization) in infants and children. This wave of research has been further buoyed by advances in online data collection and automated movement extraction technology (e.g., OpenPose). Investigating dance in pre-verbal populations raises fundamental questions. How do we define dance in naturalistic settings? What advantages (and disadvantages) are involved in automated pose extraction? What are the origins of dance behavior in human life, and what are the primary mechanisms of change throughout the lifespan? Here, we aim to integrate recent research on dance and its sub-components in infancy and childhood. Drawing from empirical work in our own labs and others in the field, we propose that investigating early musical movements is useful for understanding the development of dance itself, and that dance can also serve as a behavioural measure to better contextualize development in adjacent domains, like auditory perception and musical memory. We propose potential developmental mechanisms for understanding the emergence of dance in infancy. Finally, we highlight major methodological and theoretical considerations for advancing our understanding as we step into the future of research in early dance.

Rhythm categorization is present in human newborns and further shaped across the lifespan

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Humans across cultures show an outstanding capacity to perceive, learn, and produce musical rhythms. These skills rely on mapping the large variety of possible rhythmic sensory inputs onto a limited set of internal rhythm categories. What are the neural bases underlying rhythm categorization? One view is that rhythm categories stem from hard-wired neurobiological predispositions constraining internal representations of rhythmic inputs. However, a growing body of work suggests that rhythm categorization is plastic, specifically open to be shaped by social and cultural experience. To investigate the relative contributions of neurobiological predispositions and experience in rhythm categorization, we measured neural responses to rhythm in healthy full-term human neonates, thus capitalizing on their minimal post-natal experience. Scalp electroencephalography (EEG) was recorded from 1- to 3-day-old newborns while they were exposed to different acoustic sequences consisting of repeating patterns of two inter-onset intervals ranging from isochrony (1:1 interval ratio) to long-short patterns (2:1 ratio). In a second experiment, we separately recorded neural (EEG) and behavioral (sensorimotor synchronization) responses to the same rhythms in adult participants. The data were analyzed using a novel approach combining frequency-domain and representational similarity analyses (fRSA). Preliminary results indicate significant rhythm categorization at birth, with categories encompassing the 1:1 and 2:1 integer ratio rhythms, yet with a different categorical structure as compared to the neural and behavioral responses of adults. These findings suggest that the neural representation of rhythm may be biased towards categorical structure by neurobiological mechanisms already present at birth. These processes could be further built-upon

and shaped by post-natal experience, allowing for the emergence of diversity in music perception and behaviors observed worldwide.

Investigating Infants' Responses to Infant-Directed Singing Using Eye-Tracking

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Infant-directed (ID) singing is a rich multisensory experience that enhances bonding and synchronises behaviour between caregivers and infants. It also plays an important role in shaping early perceptual and cognitive abilities. Building on the findings of Lense et al. (2022), who studied full-term infants' visual behaviour to ID singing in English, this study aims to replicate and extend their findings with French-speaking infants. Our findings will allow for cross-linguistic comparisons and contribute to understanding the universality of ID singing's impact on infant development. Full-term infants will be shown videos of women speaking and singing in French, and their visual responses will be recorded using eye-tracking and analysed in particular during key moments of the singing. These key moments include auditory and visual cueing events, such as beats and facial expressions or gestures that are synchronised with the musical temporal structures. The analyses will prioritise fixation patterns directed at predefined areas of interest (e.g., eyes and mouth) to assess attention allocation during ID singing. Additionally, saccade dynamics–specifically their occurrence and directionality in response to or anticipation to cueing events–will be examined to understand how infants process and shift attention between auditory and visual information. Building further on Lense et al.'s findings, we will integrate additional measures, such as pupillometry to evaluate attention and arousal, and gaze alignment patterns with rhythmic cues, providing a further understanding of infants' responses to ID singing. This study aims to validate the findings of Lense et al. in a French-speaking context and offer insights into how infants engage with the rhythmic and multisensory properties

of ID singing. We will further extend this research by investigating also preterm-born infants, who are at heightened risk for neurodevelopmental disorders due to early disruptions in brain development, to explore potential differences in how they process these multimodal stimuli.

List of Posters

Tuesday Session (Day 2)

Developmental trajectories of neural markers of implicit metric processing

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Children's rhythmic and metric processing abilities are shown to predict reading skills, but the connection between these processes is unclear. This study explores the electrophysiological development of metric processing in children ages 6-to-10, to understand its relationship to reading skill. We propose that sensitivity to meter predicts reading skills in children, matures through childhood, and is disrupted in developmental dyslexia. We adapted an imagined meter paradigm validated in adults to determine the maturational trajectories of neural markers of implicit metric coding. If children's metric encoding matures during this age range, we predict that electrophysiological correlates of implicit metric structure –the N1 and late metric negativity (LMN) in response to metrically strong sounds –will increase with age. High-density electroencephalography (EEG) data was recorded from N = 41 children (out of a planned 120), while they listened to up to 40 one-minute-long trials of an isochronous stream of undifferentiated tones as repeating imagined groups of three or four. The 40 trials included 10 for each combination of listening pattern (triple, quadruple) and presentation tempo (fast, slow). Across four 15-month age cohorts, N1 amplitude in response to the probe tone increased, demonstrating the maturing of the auditory response. Moreover, across cohorts, differentiation in LMN amplitude across metric strength levels increased. In the oldest cohort, LMN amplitudes varied significantly across metric strength levels in both triple and quadruple meter conditions. Data collection is ongoing and we aim to conduct time frequency analyses to identify entrainment to both the physical stimulus and its imagined elements. We hypothesize the strength of entrainment will be predicted by age and reading comprehension skill. These results demonstrate that acoustic processing of metric structure matures between ages 6-10, and that implicit metric coding emerges during this window. The results offer insight into the relationship between meter perception and reading comprehension.

[Poster 1]

Dancing with the Starts: Exploring Sibling Interpersonal Synchrony

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Background & Aims: Joint musical play in childhood promotes prosocial behaviours and may also impact sibling relationships –young siblings' frequency of musical play positively correlates with prosociality (Cirelli et al., 2020). As a preliminary step before exploring the directionality of this effect, we conducted a feasibility study to test a "silent disco" paradigm designed to manipulate movement coordination in young siblings. Methods: Ten sibling pairs aged 3 to 7 (20 children total) visited the lab and participated in a "silent disco" dance party. Dyads were randomly assigned to hear either synchronous or asynchronous music through separate headphones. Children were encouraged to dance freely. Trials (at least 6 but up to 14) consisted of 1-min clips from music popular with this age group (e.g., "Shake it Off" by Taylor Swift). The tempo of selected music varied, and musical pairings in asynchronous trials varied by at least 15 bmp. Expected results: Videos were recorded, from multiple angles, during the "silent disco party" for subsequent analyses. Manual coding is underway to measure: (1) time spent engaging in joint dance (2) eye contact duration between dyads, and (3) sibling physical proximity during dance. We predict that dyads in the synchronous condition will dance, look, and spend time near one another more than dyads in the asynchronous condition. Conclusion: These results will inform the creation of methodology for developmental studies investigating interpersonal synchrony. Immediate results will inform the next stage of this research program, which will use the "sibling disco" manipulation explore the effects of interpersonal synchrony on sibling prosociality.

References

Cirelli, L. K., Peiris, R., Tavassoli, N., Recchia, H., & Ross, H. (2020). It takes two to tango: Preschool siblings' musical play and prosociality in the home. Social Development, 29(4), 964–975. https://doi.org/10.1111/sode.12439

[Poster 3]

Auditory neural synchronization and consciousness: EEG study with binaural beats

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Consciousness involves the flow of neuronal information strongly linked to oscillatory synchronization in the brain. The alignment between environmental rhythms and brain oscillations is known as neural entrainment, and it might play a role in states of consciousness. When it occurs in response to auditory stimuli, it is termed auditory neural entrainment - brain waves syncing with sound waves. Building on previous research about the effects of music on people with disorders of consciousness, our study aimed to characterize and modulate states of consciousness (focused attention and mind wandering) through matching and mismatching of auditory neural entrainment. Furthermore, we aimed to investigate the effect of musical training on entrainment. This study used electroencephalography (EEG) and auditory stimulation (binaural beats) to investigate auditory synchronization in 5 binaural beat (BB) conditions, matched in frequency with the brain waves delta, theta, alpha, beta and gamma. We hypothesise that neural synchronization caused by low frequency BB will increase the power of delta, theta and alpha brain waves, and high frequency BB will entrain beta and gamma brain waves, correlating with behavioral measures of focused attention and mind wandering. Understanding neural synchronization with auditory stimulation in diverse states of consciousness holds potential for future research focused on improving the rehabilitation of disorders of consciousness, as well as deepening our knowledge about the effects of sound on the brain.

[Poster 5]

Beatmatching in DJing –A study of audio-motor interaction using EEG and TRF

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This study investigates the neural mechanisms underlying beatmatching in DJs, a key skill in live dance music performance. Beatmatching involves synchronizing the tempo of two tracks to simultaneously mix or seamlessly transition between tracks, requiring precise auditory-motor coordination. Despite its importance in DJing, the process of beatmatching remain largely unexplored. This research employs the Temporal Response Function (TRF) analysis technique to predict brain activity from recorded audio during beatmatching tasks. Participants in the study were professional DJs (minimum two years of experience) with experience in beatmatching by ear. They were asked to a beatmatch two custom designed beat tracks under two starting conditions: a) with a phase difference (60%) and b) with a tempo difference (5 bpm). The beatmatching process was divided up into 5 phases: listening to track A, listening to track B, listening to both tracks simultaneously, beatmatching track A to track B, and monitoring the mix. Their brain activity was recorded using 64-channel electroencephalography (EEG). The produced audio mix was recorded through a MIDI patch. We used the recorded audio as input for the TRF analysis, which models the relationship between the auditory stimulus and the corresponding neural response. Preliminary analyses show that the audio signal predicts the brain activity best 50 ms prior to the audio signal during the listening phases, indicating anticipatory neural responses. The response showed auditory and central motor projections. The paper will present additional analyses on the dynamic networks during beatmatching, specifically surrounding different matching behaviours (e.g., slip cueing). These findings provide new insights into the cognitive and neural processes involved in DJing, suggesting that beatmatching relies on a network of brain regions that coordinate auditory perception and motor execution. TRF analysis offers a novel approach to studying the dynamic interplay between sensory input and neural activity in real-time music performance.

[Poster 7]

Measuring Temporal Accuracy in Dynamic Tempo Performances with MIDI Instruments: A Novel Approach Using Accessible and Open-Source Resources

C. Bayle[1]***, A. Berg***[1]***, B. U. Cowley***[1]

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We present a novel system for measuring rhythmic performances on MIDI instruments over dynamic tempo sequences, providing a score for temporal accuracy. It is developed using accessible, open-source resources, specifically the "Reaper" DAW and the "Mido" Python library. The method consists of creating a tempo map in the DAW, defining time windows for temporal accuracy based on rhythmic notes, and integrating these into custom Python scripts for recording and analyzing performances. We outline the system's conceptual framework and demonstrate its application using an example from our study on drum rudiment practice over an "open–close–open" dynamic sequence (acceleration, hold peak tempo, and deceleration). Additionally, we present results and strategies for assessing the system's reliability. A key advantage of this method is its use of accuracy intervals that adapt proportionally to tempo changes, achieved without relying on mathematical notation potentially unfamiliar to music researchers. Instead, the approach involves using musical rhythmical figures and the graphical interface of the DAW, making it significantly more accessible to musicians for conducting performance time measurements. Our goal is to explain the method in a way that enables other researchers to easily adapt its code and premises to their studies, particularly those involving tempo mapping or performance accuracy scoring.

[Poster 9]

Discerning the real-time effects of mind wandering on musical creativity: A psycho-phenomenological study of jazz improvisation

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Mind wandering (MW) is a prevalent and ubiquitous phenomenon that despite its negative effects on cognitive processes like working memory, sustained attention, or response inhibition, has found in later years increasing evidence that it could play a key role in creative cognition. While studies suggest that MW benefits creativity if it occurs in the incubation period of a creative problem-solving task, it remains unclear if MW during the course of a creative task benefits the real-time expression of creative behaviour. Musical improvisation provides an ecologically useful framework for studying the real-time effects of MW on creativity. Indeed, a recent preliminary study by the present authors suggested that MW during a jazz improvisation task enhanced the creativity of musical improvisation in expert pianists, compared with improvisation during on-task attention. Here, we aim to replicate these findings with a bigger sample size and a more refined experience sampling methodology that not only captures mind wandering, but also other off-task thought phenomena, namely mind blanking and task-related interference. Therefore, we ultimately aim to discern the real-time impact of each type of off-task phenomena on ongoing musical creativity. 52 jazz musicians of various levels of expertise underwent a series of jazz improvisation tasks interleaved with random experience sampling probes. We expect to replicate previous findings of MW-associated enhancement of musical creativity. We also expect that this effect will be more prevalent in proficient musicians, compared to novices. Finally, we expect that mind blanking and task-related interference will pose instances of off-task thought that do not positively affect improvisatory performance. Should we obtain our expected results, this investigation will sediment our previous claim that mind wandering during improvisation is associated with a significant increase in musical creativity. It will also provide the first account of the real-time impact of different attentional states on musical performance.

[Poster 11]

Do the Musicians Play Well in Rhythm Together? A New Beat Alignment Task to Assess Rhythmic Abilities in Children

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Recent research underscores the role of rhythm processing in music and language, also revealing atypical patterns in children with neurodevelopmental language disorders. Existing tools for assessing rhythmic skills often target adults, highlighting the need for child-friendly, more musical and shorter tasks. Our work focuses on beat perception and production, aiming to study underlying cognitive processes and developmental trajectories. We designed a novel version of the seminal Beat Alignment Test (BAT) for children using pop-music-style excerpts with an integrated kick drum instead of an external triangle. The new songs with the kick received higher ratings in "pleasure", "wanting to move," and "pulse clarity" compared to the songs with the triangle, suggesting the kick's stronger association with groove. Three versions of the excerpts were created, with the kick playing on beat, earlier or later. Participants were asked to judge whether the musicians were playing well in rhythm together or not. Pretests with adults confirmed the task's feasibility. The new task was rather short (6 minutes), suggesting suitability for young participants. Testing 8-year-old children revealed they also succeeded to complete this task, with performance correlating with performance of the BAT. We also assessed language skills using a reading test aiming to further investigate the relationship between rhythmic and language abilities. We will extend the testing to younger children (6–7 years) using the current methodology, and we will then refine it further for testing even younger age groups. Ongoing work applies a sensory-motor-synchronization task to the same music as well as isochronous tone sequences to investigate rhythm production skills. To complement behavioral assessments, we are piloting eye-tracking measures to examine pupil dilation in response to beat violations. These indirect measures may reveal cognitive mechanisms underlying rhythm and beat perception that explicit judgments might not be able to capture, in particular in younger populations.

[Poster 13]

Infant Attentional and Physiological Responses to Live Maternal Infant-Directed Singing

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Infant-directed (ID) singing has traditionally been divided into playsongs and lullabies. Their distinct acoustic features are argued to have specific functions - to arouse and soothe, respectively. Previous studies have investigated the acoustic qualities of ID singing and infant reactions to it separately. However, in the performative context of ID singing, it is crucial that caregivers and infants react to each other's signals for optimal song function. In this study, we observed face-to-face ID singing of a playsong and a lullaby in 74 mothers and their 7-month-old infants. We measured variability in maternal singing via spectral flux around the onset of infant attention via social gaze toward their mother. In a subset of 30 infants, we additionally investigated the physiological effects of ID singing on infants. Results showed that maternal acoustic variability and infant attention were higher overall in playsongs over lullabies (spectral flux: $p<.001$; social gaze: frequency $p<.001$, duration: $p<.001$, relative duration: $p=.01$). To explore the contingency of fine-grained maternal acoustic variability alongside infant attention, we conducted permutation analyses (nperm = 1000). Infant attention was especially increased after the onset of infant attention in playsongs ($p<5/2$ percentile). Preliminary analyses of infant physiology (N=30) show an upregulating trend of playsongs but no regulatory effect of lullabies, measured via respiratory sinus arrythmia ($p=.09$), which matches the function of playsongs. Combined, our results suggest that mothers increase acoustic variability both to modulate and respond to infant attention in the appropriate context, i.e. during playsongs, and infants respond to their mothers' more variable singing by paying more attention to her and upregulating themselves during playsongs, but not during lullabies. Thus, we propose that ID singing interactions have regulatory functions and elicit reciprocal responses between maternal acoustic variability and infant attention that are context-dependent.

[Poster 15]

Exploring the impact of tactile stimulation on rhythm perception in newborns

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Rhythm perception is of fundamental importance for early development. In adults, sensorimotor mechanisms play an important role in rhythm perception and beat-based predictions. Early in development, patting newborns and young infants in time with music to soothe them or facilitate sleep serves as a natural and age-appropriate rhythmic stimulus. However, it remains unclear whether the auditory-sensorimotor interaction observed during later developmental stages is present in neonates and if auditory rhythm perception can be modulated by sensorimotor input. Our study investigates the neural following of auditory rhythms in lullabies and its modulation by tactile stimuli in newborns, aiming to better understand early auditory-sensorimotor integration. We will recruit 40 full-term newborns (born at 38-40 weeks gestational age) and evaluate their neural activity in three conditions using electroencephalography (EEG): (1) Auditory-tactile, where lullabies with a beat at 2Hz (120 beats per minute) are paired with simultaneous 1 Hz (at the strong beat) patting; (2) Auditory-only, where infants only hear the lullabies, (3) Tactile-only, where rhythmic tapping at 1 Hz is delivered in silence. Our initial analyses will investigate the separate contributions of auditory and tactile stimuli by comparing neural activity across the auditory-only and tactile-only conditions. Our primary analyses will evaluate whether auditory-tactile stimulation improves neural following of the lullaby rhythms and enhances synchronization to the strong beat, compared to the auditory and tactile stimulation. Specifically, we will present results from coherence analyses between the envelope and spectral flux of the lullabies and the low-frequency EEG signals in the auditory-tactile condition compared to the auditory and tactile conditions. This study will shed light on how neonates process multimodal rhythmic stimuli, highlighting the potential effect of patting–a natural and intuitive stimulus for infants–as a means to influence rhythm perception and support the development of auditory-sensorimotor integration at this early stage.

[Poster 17]

Analysis of Mental Effort and Theoretical Complexity in the Perception and Reproduction of Rhythmic Sequences

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Several definitions and measures of musical complexity exist in the literature, particularly regarding its rhythmic aspects [1,2]. Different types of rhythmic tasks (perception or production, reading or listening, etc.) can be perceived as more or less complex, and can require different levels of cognitive resources. For instance, a relationship has been found between specific physiological factors and perceived effort in the context of music listening [3]. This work is a preliminary study towards the understanding of the relationship between mental effort and rhythmic complexity. To that end, we collected data of participants performing two related tasks: beat perception and rhythmic sequence reproduction. These data include subjective data (perceived effort), performance data (precision during the tasks) and physiological data (electrodermal activity). This study explores the correlation between these data and complexity metrics from the literature. We therefore explore the evaluation of the mental effort associated with certain rhythmic sequences and relate it to existing metrics, which can give another point of view on rhythmic difficulty. Our results suggest that some objective metrics better fit the perceived difficulty of advanced musicians depending on the task. Although we observed a relative disparity between the corresponding results, we also found some promising correlations between physiological factors and perceived effort ratings. Being able to correctly vary rhythmic difficulty would have applications in various fields such as musical pedagogy, music generation and recommendation or even music therapy.

References

[1] Povel, D. J., & Essens, P. (1985). Perception of temporal patterns. Music perception, 2(4), 411-440.
[2] Thul, E., & Toussaint, G. T. (2008). Rhythm Complexity Measures: A Comparison of Mathematical Models of Human Perception and Performance. In ISMIR (pp. 663-668).
[3] Bishop, L.E & Bonnin, G. & Frey, J. (2023). Analysing Physiological Data Collected During Music Listening: An Introduction. In 24th International Society for Music Information Retrieval Conference.

[Poster 19]

Are parrot entrainment capabilities rooted in their natural repertoire? A dive into the budgerigars' vocalisations

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Beat perception and synchronisation (BPS) is one the behavioural and cognitive traits underlying the culturally shaped phenomenon of human music. This trait is shared across almost all human individuals, and appears to be biologically innate. As such, the discovery of BPS in non-human animals could be informative regarding the evolution of music and musicality and the selective pressures involved. Among the "dancing" (through motor entrainment) species described thus far, parrots seem to be the most proficient, which is possibly related to their uniquely "spontaneous" and self-motivated engagement with this behaviour. Little is known about the mechanisms of BPS in non-human animals though, or why parrots would be producing this complex behaviour at all. Budgerigars (Melopsittacus undulatus) are a commonly used parrot model species, and although their entrainment capabilities are limited compared to some other parrot species, they surpass any primate species studied thus far including the human's closest living relative, the chimpanzee. Hypothesising that entrainment capabilities originate from parrot natural behaviour, we investigated the rhythmic structure of the budgerigars' warble vocalisation. The budgerigar warble is a temporally complex vocalisation, which has been associated with repetitive, or isochronous, motor behaviours like head- bobs or jerks. Individual elements were extracted and labelled from warble recordings of 14 budgerigars from 4 different captive groups. Temporal structure related to the onsets (inter-onset-intervals) of these elements were compared to recordings of naturalistic human vocalisations, i.e. speech, analysed using similar methods. Preliminary results based on IOI ratio indicate different patterns related to different warble elements, ranging from isochrony for alarm(-like) elements to human speech-like patterns for the complex (compound) warble elements. Further analyses based on large scale patterns related to utterances (bouts) will be conducted later and presented at the conference, however these preliminary results already suggest flexible and complex temporal patterns in budgerigar vocalisations.

[Poster 21]

Assessing the contribution of lower-level neural mechanisms to rhythm categorization in humans

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Humans effortlessly learn, recognize, and move to musical rhythms. This ability builds on a categorization process that spontaneously maps the vast diversity of external rhythms onto a limited repertoire of discrete internal categories. However, the neural mechanisms underlying rhythm categorization remain largely unknown. For example, it could be hypothesized that two fundamental mechanisms, namely anisochrony detection (i.e. differentiating even vs. uneven rhythms) and nonlinear neural adaptation (i.e. sharp suppression of the response to a sensory event close in time to the preceding event, thus differentiating markedly uneven vs. less uneven rhythms) play a necessary role in this process. Here, we move a critical step forward in our understanding of rhythm categorization by probing whether rhythm categories spontaneously emerge in brain activity even in response to a set of rhythmic sequences specifically equalized in terms of unevenness, thus allowing to rule out the necessary contribution of anisochrony detection and/or neural adaptation to rhythm categorization. This was tested by recording brain activity of healthy participants using electroencephalography (EEG) as they were listening to these sequences, and capitalizing on a novel approach recently developed to capture rhythm categorization in brain activity. Complementing the EEG data, participants' sensorimotor synchronization (finger tapping) with the same stimuli was measured to obtain a behavioral index of rhythm categorization. Preliminary results indicate that rhythm categorization goes beyond non-specific fundamental neural mechanisms of adaptation and anisochrony detection. Accordingly, these findings may open the way to further investigation of alternative, higher-level neural mechanisms explaining rhythm categorization, especially its cultural variability, by leveraging the cultural specificity of some rhythm categories and comparing responses across groups differing in lifelong experience with these rhythms.

[Poster 23]

Effects of Learning on Neural Representations of Rhythm and Beat

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Listening to rhythmic sounds elicits activity in the basal ganglia, cerebellum, and motor cortices, including supplementary motor area and premotor cortex. Rhythms with musical structure that give rise to a steady underlying pulse, or 'beat', elicit increased activity in the SMA and basal ganglia, suggesting these areas are involved in beat perception. However, because much of the music people listen to has a clear beat, rhythms eliciting a strong beat may also be more predictable because of their familiarity than amusical, irregularly-timed rhythms that are often used as control stimuli. Thus, neural correlates of beat perception may be confounded by the relative familiarity of strong-beat rhythms. To address this confound, we increased the familiarity of a subset of rhythms that vary in beat strength, and measured BOLD activity associated with the rhythms before and after familiarity was increased. Across 4 sessions, participants trained on 12 unique rhythms (4 strong-beat, 4 weak-beat, and 4 non-beat) in finger tapping tasks. In pre- and post-training fMRI sessions, we measured BOLD responses while participants listened to the rhythms during a rhythm discrimination task. Preliminary results reveal no influence of familiarity on the neural representation of beat –strong-beat and non-beat rhythms elicited significantly dissimilar activity patterns in the SMA and putamen both in pre-training and post-training scans. The only effect of training was an increase in dissimilarity between activity patterns in these regions, suggesting that learning the rhythms only made activity more distinct between beat strength conditions. Overall, this suggests the SMA and putamen do not simply encode the familiarity or predictability of rhythms, but are likely involved in beat perception itself.

[Poster 25]

Wednesday Session (Day 3)

Impact of Tempo Fluctuations on Brain Dynamics during Naturalistic Music Listening

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Several studies have examined the effects of tempo variations on the brain in both controlled and naturalistic experimental settings, using either short musical excerpts with different tempos or gradual tempo changes, proving the engagement of auditory, motor and emotion-related brain areas. However, these studies have not focused explicitly on real-time tempo fluctuations, or how they may affect musicians and non-musicians differently. This study investigates how tempo fluctuations impact brain dynamics during naturalistic music listening, aiming to bridge the gap between artificial music listening conditions and real-world experiences, using real musical pieces with diverse tempo variabilities. Brain dynamics here refer to the changes in neural activation and patterns, involved in processing, adapting to, and responding to music. The data used comes from a previously collected fMRI dataset, where thirty-six healthy participants (18 female) listened to three musical pieces while undergoing fMRI. Half of the participants were professional musicians, while the rest were non-musicians. Each piece lasted approximately 8 minutes and had different levels of tempo variability and instability. Tempo was extracted using MIR Toolbox, and its rate of change was quantified by calculating the derivative of tempo over time. These data were correlated with the fMRI time series, and group differences were tested using non-parametric t-tests. It is expected that motor system areas will be activated during fluctuating tempos, including the premotor cortex, basal ganglia, cerebellum, and supplementary motor area. Additionally, tempo accelerations are expected to induce an increased frontal activation in the left hemisphere and temporal cortex. The results will provide further insights into the neural mechanisms underlying tempo fluctuations while enhancing our understanding of how the brain processes complex auditory stimuli in real-world contexts. Furthermore, these insights could have applications in neurologic music therapy and inform therapeutic strategies for motor recovery after brain related injuries.

[Poster 2]

Individuals with substance use disorders experience stronger groove with high rhythmic and harmonic complexity

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The pleasurable urge to move to music –also known as groove –is a fundamental aspect of musical and social experiences. Several studies indicate that music with moderate, compared to low and high, rhythmic complexity induces the strongest groove experience. The resulting inverted U-shaped relationship between rhythmic complexity and groove can be interpreted within the framework of predictive processing: moderately complex rhythms generate the highest number of strongly weighted prediction errors, which occur when the internal model of beat and meter and the rhythmic input mismatch. Resolving these prediction errors is associated with increased motor system activity and reward, likely involving the neurotransmitters dopamine and norepinephrine. In substance use disorders, dopamine release and receptors are decreased, which may increase the threshold for non-drug related environmental stimuli to elicit rewarding experiences. In addition, psychostimulants and opioids affect norepinephrine, which plays a crucial role in arousal and is linked to dopamine signaling. Building on these findings, we examined how substance use disorders affect the experience of groove. We compared ratings of the urge to move to music between participants in rehabilitation for heroin and cocaine addictions (n=35) and a no-drug control group (n=23). Stimuli were previously used sequences of piano chords systematically varying in rhythmic and harmonic complexity. Results show that drug users, compared to non-users, experienced stronger groove with high rhythmic and harmonic complexities, while moderate complexities elicited similar responses across groups. This pattern is distinct from other populations with altered dopaminergic functions, such as Parkinson's disease or musical anhedonia, and reveals a unique effect of drug addiction on music perception. The findings suggest that drug users are more likely to seek intense and complex external stimulation, supporting the hypothesis that drug-related disruptions in dopamine signaling increase the threshold for non-drug related environmental stimuli to engage the reward system.

[Poster 4]

Learning through repeated exposures modulates the relation between rhythmic complexity and state curiosity

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When listening to rhythmic music, listeners often experience a pleasurable urge to move along to the underlying beat, referred to as PLUMM. This response is particularly strong for rhythms with medium degrees of complexity and is weaker for rhythms with low or high degrees of complexity. A recent formulation suggests that this inverted U-shaped relation between rhythmic complexity and PLUMM is driven by an intrinsic motivation for perceptual learning. In this account, medium complexity rhythms maximally enable improvement to rhythm-based predictions, and experience of this improvement elicits a pleasurable, curious state. This suggests a strong link between PLUMM, state curiosity, and learning. Specifically, state curiosity should also show an inverted relation with rhythmic complexity and this relation should be modulated as listeners gain familiarity with the rhythms. To test this, rhythms (n = 9) with three levels of complexity were presented to participants (n = 181) in an online study. The rhythms cut off in the middle of the fourth bar and participants rated how curious they were about how the rhythm would unfold following the cutoff. Participants repeated this task over three blocks. Curiosity ratings showed an inverted U-shaped relation between rhythmic complexity and curiosity in the first block which then flattened out over the second and third blocks. Importantly, this flattening was driven by an increase in curiosity, particularly for high complexity rhythms, which contain the most learning potential, while ratings for medium complexity rhythms remained stable over blocks. Curiosity also correlated with pleasure ratings, which also showed the inverted U in relation to rhythmic complexity, substantiating the link between pleasure and curiosity. Together these results support a link between PLUMM, state curiosity, and learning. Ongoing work will investigate the specific time course of the learning effect, as well as the influence of trait curiosity.

[Poster 6]

Metric expectations drive auditory-motor connectivity: a combined TMS-EEG study

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Motor and premotor regions are theorized to generate timing predictions which auditory regions use to effectively perceive or imagine a beat. This strong auditory-motor coupling is bidirectional and involves -band oscillations, as shown in prior electroencephalography (EEG) studies. Previous transcranial magnetic stimulation (TMS) research by our lab found that the right dorsal premotor cortex (dPMC) is critically involved in this process. In this study, we combined TMS stimulation and EEG recording to investigate the cortical excitability under different states of beat-based timing perception and prediction. Participants listened to or imagined accents during the presentation of an auditory tone sequence that created a march (binary) or a waltz (ternary) metric structure. EEG was recorded throughout the experiment, as single TMS pulses were delivered 50ms before either accented or unaccented events on the right dPMC. We measured neural excitability changes via TMS-evoked potential (TEP) amplitudes, and we investigated directed functional connectivity between dPMC and auditory regions. We expect increased TEP amplitudes for accented compared to unaccented events, in both the physical and imagined conditions, indicating greater dPMC reactivity when metric expectations are stronger. Additionally, if dPMC encodes metrical expectations, dPMC-to-auditory connectivity should be stronger than auditory-to-dPMC connectivity. Specifically, we predict this effect to occur in delta and in beta frequency bands, given the importance of these frequencies in motor processes. Together these results would clarify the causal relationships between premotor and auditory regions, highlighting the predictive role of the premotor cortex in metric processing.

[Poster 8]

Neural entrainment and working memory as predictors of sensorimotor synchronization skills

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Neural entrainment to rhythmic patterns has been proposed as a mechanism that underlies beat perception and could explain individual differences in sensorimotor synchronization abilities. Nonetheless, the neural and cognitive mechanisms behind our ability to perceive the beat remains an active research area. Our study examined whether neural entrainment to rhythmic patterns with explicit (unsyncopated) and implicit (syncopated) beats, cognitive resources, specifically working memory and musical background could predict sensorimotor synchronization skills in adults. Using Electroencephalogram (EEG), we recorded steady-state evoked potentials (SS-EPs) while participants passively listened to syncopated and unsyncopated rhythms. Participants also completed a finger-tapping task, measuring tapping consistency and asynchrony, a musical background questionnaire and a counting span task to assess working memory. Results showed increased SS-EPs at beat-related frequencies (1.25 Hz and its harmonics, 2.10/2.50 Hz, 5 Hz), indicating faithful neural tracking of the rhythms. A stepwise regression analysis revealed SS-EP amplitudes to explicit beats and counting span as the best predictors of tapping consistency. Participants with reduced SS-EP amplitudes and higher working memory capacity demonstrated greater tapping consistency. This is contrary to earlier studies that link stronger entrainment to rhythmic patterns with better sensorimotor synchronization skills. This discrepancy may reflect distinct neural mechanisms underlying beat-based versus memory-based rhythmic expectations, as stronger entrainment to beat-based stimuli may reduce the flexibility needed for tapping tasks reliant on memory-based predictions. In our results musical background was not a significant predictor of tapping performance, while working memory was, suggesting that individual differences on working memory support rhythm production skills by maintaining internal representations of time intervals. The results highlighted the multidimensionality of rhythm processing, and the complex relationship between neural entrainment and sensorimotor synchronization skills.

[Poster 10]

Neural entrainment to rhythmic speech in adults with developmental dyslexia

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This EEG study seeks empirical evidence on the contribution of rhythm skills to the development of phonological and reading skills, aiming to help to inform remediation strategies. In recent years, it has been argued that early sensory difficulties with acoustic rhythm patterns may underlie the difficulties in acquiring written language experienced by children with developmental dyslexia (DD). This 'Temporal Sampling' theory predicts that neural sampling of auditory information at slow rates (<10 Hz, related to speech rhythm) is atypical in individuals with DD, particularly in the delta band (0.5-4 Hz). Here we examine the underlying neurophysiological mechanisms related to atypical sampling using a simple repetitive speech paradigm. We are evaluating 40 non-musician adults, 20 with a history of DD. They are exposed to an auditory sequence of isochronous repeated syllables (SOA of 500 ms; 2 Hz delta band rate) while their brain activity is measured using EEG. Based on previous findings (Keshavarzi et al., 2022; Power et al., 2012, 2013), we expect to observe significant phase consistency for both groups in the delta and theta bands, demonstrating neural entrainment. However, participants with DD may show atypical neural response, marked by a significantly reduced phase consistency and a different preferred phase compared to controls in the delta band. Furthermore, these neurophysiological measures are expected to be related to the severity of participants' phonological and reading deficits. Results will be discussed in light of the Temporal Sampling Framework of Goswami (2011). They may contribute to a better understanding of the neural factors underlying DD across languages and pave the way for new avenues of remediation.

[Poster 12]

Neural responses at binarized and ternarized metrical positions in polyrhythms

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Mismatch negativities (MMN) to intensity-modulated sounds vary based on their position within the metrical structure, with stronger MMNs at on-beat than off-beat positions [1]. Polyrhythms consist of two or more pulses, with rates related by coprime numbers, aligned at the start of each cycle repetition. Perception of polyrhythms is biased towards beats admitting binary groupings of the common metrical subdivisions [2]. This study aims to investigate neural responses to these complex rhythmic structures and explore how prediction errors differ across metrical positions. We expect larger MMN amplitudes at binarized than ternarized beat-related positions. We also expect that finger-tapping responses and frequency-tagged neural amplitudes will reflect the preference for binarized beats. We aim to record electroencephalography of 32 healthy participants while they watch a muted video. Percussive 2:3 and 3:4 polyrhythms are presented at two tempi with intensity deviants (-12 dB) introduced randomly. Jittered versions of the polyrhythms are included as control stimuli to isolate the effects of auditory deviance detection. After the recordings, we ask participants to tap to the beat of each polyrhythm. We report results of an ongoing study. First analyses indicate that deviants elicit MMNs at positions related to the binarized and ternarized beats, with larger MMNs at the downbeat position. MMNs also appear in response to jittered stimuli, which reflect automatic deviance detection mechanisms in unstructured sequences. Frequency tagging shows peaks at binarized and ternarized beat frequencies across polyrhythms, but not in the jittered stimuli. Full dataset analyses will elucidate the hypothesized differences between binarized and ternarized metrical positions, and provide insights into the neural basis of the bias [2]. This study will also clarify how the brain selects the beat in ambiguous rhythms and allocates attention to relevant time points.

References

1-Bouwer, et al. (2016). Neuropsychologia, 85.
2-Møller, et al. (2021). Plos one, 16.

[Poster 14]

Real and Virtual Juggling as a Model for Complex Sensorimotor Synchronization

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Sensorimotor synchronization (SMS) has been extensively studied, typically using comparably simple motor tasks like tapping or stepping to a beat. Such research has provided substantial insight into the factors influencing SMS, including multisensory perception and attention. In our research, we ask which principles transfer from such externally-paced tasks to naturalistic partially self-paced rhythmic activities. As a model for such activities, we use juggling. To make juggling experimentally controllable and readily accessible to non-experts, we employ a guided two-dimensional juggling version, where participants throw (i.e., roll) balls up an incline with rails (the "juggle board"). In our study, we ask participants in different blocks to "juggle" either one or two balls with this board; that is, to try and roll the ball(s) rhythmically a specific uphill distance (i.e., control the amplitude and frequency of each ball's oscillation and –in the case of two balls –their relative phase). As we intend to extend this paradigm to study perturbations that are hard or impossible to physically implement, we compare the real-world juggle board to a virtual-reality (VR) version. In both settings, participants perform the same tasks. In addition to tracking the position and orientation of hand and head, we also measure gaze orientation as a proxy for attentional allocation. Preliminary data demonstrates that our setup allows the quantification of a variety of parameters related to SMS (e.g., the amplitude, phase and frequency of the balls' oscillations, the time of contact between hand and ball, motor patterns of hand and wrist, gaze parameters). Comparing these parameters between VR and the real world will provide a critical test as to whether juggling in VR can indeed provide a naturalistic and well-controllable model for complex partially self-paced SMS tasks.

[Poster 16]

The impact of short-term synchronization training on pre-existing rhythm priors

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There is evidence that a fundamental component of rhythm perception is the formation of perceptual categories of small-integer ratios, known as rhythm priors. Rhythm priors appear to be shaped by cultural exposure, and are apparent in musicians and non-musicians alike. However, it is unclear how and when rhythm priors are acquired. To explore how rhythm priors are formed, this study trained participants on an unfamiliar rhythm ratio and measured their ability to synchronize with and to discriminate different rhythms both before and after training. Participants were asked to tap or listen to a rhythm with a complex 4:3 integer ratio during training, which is an uncommon rhythm prior in most western musical traditions and difficult to synchronize with for unfamiliar listeners. Ten minutes of tapping to the unfamiliar 4:3 rhythm ratio resulted in an improvement of participants' synchronization to the 4:3 rhythm prior category. Additionally, in the adjacent 2:1 rhythm prior category, participants showed a change in synchronization after training on the 4:3 rhythm ratio, but not after training on the 2:1 rhythm ratio. These early results suggest that short-term training results in rhythm prior re-weighting, solidifying the trained rhythm while possibly weakening adjacent existing rhythm priors. Alternatively, the existing adjacent rhythm prior may be changing to integrate the training rhythm. Overall, the results imply that new rhythm priors can be initially shaped by a minimum amount of training, indicating some short-term malleability. Further observation will be needed to determine the duration and amount of exposure necessary to form a new rhythm prior.

[Poster 18]

The role of beat perception and executive functions in early reading development

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A growing body of research supports the relationship between children's beat perception skills and reading development. However, the roles of phonological awareness, general cognitive abilities, and executive functions in this relationship remain unclear. In the present study, we tested 40 Hungarian children on their general cognitive abilities and executive functions (verbal and spatial working memory, non-verbal reasoning, rapid naming, planning, inhibition), language and literacy skills (word reading and phonological awareness), and beat perception during their first school year. Our test battery included an adaptive digital bundle of executive function and literacy tests developed at Eötvös Loránd University, Budapest, as well as two child-friendly adaptations of well-known adult instruments for measuring beat perception. These included a graphical 12-item version of the Beat Alignment Test (Grahn & Brett, 2007; Trainor & Einarson, 2016) and an adaptation of the Beat-Based Advantage test (Iversen & Patel, 2010; Ladányi et al., in progress), in which animal puppets drumming to the beat of complex musical stimuli are presented. Our results may help identify early predictors of reading, including the interplay between beat perception, phonological awareness, and executive functions. In line with the growing body of literature, our findings suggest that beat perception is an early predictor of reading skills, making it a potentially useful tool for diagnosing reading difficulties. This highlights the importance of early rhythmic development and musical education as protective factors against later reading challenges.

[Poster 20]

Three simple models to generate integer ratios between temporal intervals

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An intriguing commonality across diverse musical traditions and species is categorical rhythms. The time between the onset of an event and the next one often conforms to small integer ratios: intervals whose relative durations can be expressed as fractions of two integers. Understanding the mechanisms of such patterns can reveal the cognitive and biological foundations of rhythm. We compared three simple computational models, applicable beyond humans, which produce temporal sequences with inter-onset intervals (IOIs) related to integer ratios: Markov chains, spiking neural networks (SNN), and a model inspired by cricket stridulations. The Markov chain models rhythmic transitions as a memoryless process. The SNNs generate rhythms inspired by the temporal processes of biological neurons. The cricket model offers ecological validity and insights into cross-species rhythmic behaviors. Each model uses distinct generative mechanisms, providing complementary perspectives on rhythmic behavior. Results from the Markov chain model demonstrate how simple stochastic processes can generate integer ratios and how transition probabilities and spread of IOI distributions influence the rhythm ratio distribution. Computational simulations of both the SNN and cricket model show how they transform random input sequences into structured isochronous rhythms. These results support the idea that intrinsic properties of neurons and basic biological feedback loops can produce rhythmic categories and integer ratios. Additionally, SSNs, involving nonlinear mechanisms, give rise to a greater diversity of rhythmic categories beyond isochrony. Our findings suggest that some rhythmic patterns in music and animal vocalizations may stem from shared, fundamental processes, providing benchmarks in the study of rhythm evolution and musicality. They also question why not all species show integer ratio categories if they are so simple to achieve. These models provide a foundation for future comparisons with more complex models incorporating higher-order cognitive processes, such as adaptive learning, to clarify whether they are necessary to produce integer ratios.

[Poster 22]

Unlocking the pleasurable urge to move to music in people with Parkinson's disease through rhythm and social connection

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Introduction: Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects motor and non-motor functions, reducing quality of life. Music-based interventions, particularly Rhythmic Auditory Stimulation (RAS), have shown to enhance motor function and emotional well-being by engaging motor and reward networks. However, many studies overlook the social dimension of music, which may further enhance therapeutic outcomes. This study examines how social interaction and rhythmic complexity influence the pleasurable urge to move to music (PLUMM), beat-related movement, and timing consistency in individuals with PD non-PD controls (C). Methods: Seventy-eight participants (41 PD, 37 C) completed a finger-tapping task under three conditions: auditory, audiovisual, and social (with an experimenter). They tapped to rhythms of four complexity levels (isochronous, low, moderate, high). PLUMM ratings, beat-related movement (video recording analysis), and timing consistency (inter-tap interval variability) were analyzed using linear mixed-effects models, with additional correlations examined for empathy traits, music reward sensitivity, and felt synchronicity. Results: PLUMM ratings showed a three-way interaction driven by a significant main effect of rhythmic complexity. No condition effects were found in C, but in PD, the social condition elicited higher ratings than auditory and audiovisual conditions, particularly at moderate and high complexities. Beat-related movement improved significantly in the social condition compared to auditory and audiovisual conditions, but only in PD for high complexity. Tapping variability of PD participants was significantly influenced by rhythmic complexity and condition, with greater consistency in the social condition at higher complexity levels. Conclusion: Social interaction enhances PLUMM, beat-related movement, and timing consistency in PD, highlighting the need for social dimensions in music-based interventions. These findings suggest that rhythmically engaging, socially interactive interventions may optimise therapeutic outcomes for individuals with PD, with implications for rehabilitation and well-being in aging populations.

[Poster 24]

How does music training influence the effect of synchrony on social bonding?

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The need for establish bonds with others is a basic aspect of interactions between individuals and groups, making it key for healthy societies (Savage et al., 2020). Music being present when interacting with others seems to have a positive effect in the formation of social bonds (Bamford et al., 2023; Pearce et al., 2015; Tarr et al., 2016; Vuoskoski et al., 2017). Movement synchrony has been found to play a crucial role in this (Launay et al., 2016). Music training (MT) can enhance a persons ability to synchronize with others (Tranchant et al., 2022). However, the influence a persons previous MT has on synchrony accuracy, and how this affects social bonding remains unclear. We hypothesize that more accurate synchronizing from prior music training will increase perception of social bonding. For this, 64 participants (32 pairs) did several randomized coordination exercises, with different coordination (synchrony, anti-phase) and leadership (leading, following, and joint) conditions. These exercises were recorded using motion capture, with markers on the fingers used. They also completed a series of questionnaires before and/or after the exercises: the MT subscale of the Gold-MSI, Inclusion of Other in the Self (IOS) Scale, short PANAS, a familiarity scale, and three novel items created by Taylor (2019) designed to measure team click. For the statistical analysis, participants were grouped according to their score in the MT subscale. Preliminary results show no correlation between overall MT and Change in IOS scale. However, they indicate that there is a positive correlation between Change in IOS scale and musical training for the MHMT group (P = .025), but not for the LNMT group (P = .057). Analysis of the motion capture data is still ongoing. The implications of this study will be discussed.

References

Bamford, J. S., Tarr, B., Miles, L., Cohen, E. (2023). Drumming in time is easy: social bonding effects of synchrony arise from reduced cognitive load. ICMPC17-APSCOM.
Launay, J., Tarr, B., Dunbar, R. I. M. (2016). Synchrony as an Adaptive Mechanism for Large-Scale Human Social Bonding. Ethology, 122(10), 779789.
Pearce, E., Launay, J., Dunbar, R. I. M. (2015). The ice-breaker effect: singing mediates fast social bonding. Royal Society Open Science, 2(10).
Savage, P. E., Loui, P., Tarr, B., Schachner, A., Glowacki, L., Mithen, S., Fitch, W. T. (2020). Music as a coevolved system for social bonding. The Behavioral and Brain Sciences, 44.
Tarr, B., Launay, J., Dunbar, R. I. M. (2014). Music and social bonding: Self-other

merging and neurohormonal mechanisms. Frontiers in Psychology, 5(SEP), 103498.
Tarr, B., Launay, J., Dunbar, R. I. M. (2016). Silent disco: dancing in synchrony leads to elevated pain thresholds and social closeness. Evolution and Human Behavior, 37(5), 343349.
Taylor, J. (2019). Social bonding through joint action: when the team clicks. OSF. https://doi.org/10.31219/OSF.IO/DVNT4
Tranchant, P., Scholler, E., Palmer, C. (2022). Endogenous rhythms influence musicians and non-musicians interpersonal synchrony. Scientific Reports 2022 12:1, 12(1), 114.
Vuoskoski, J. K., Clarke, E. F., Denora, T. (2017). Music listening evokes implicit affiliation. Psychology of Music, 45(4), 584599.

[Poster 26]

Useful Information

Talks will be held at the Auditorium (M103) of the **Department of Music, Art, and Culture Studies** of the University of Jyväskylä, in the **Musica** building. It is located in Seminaarinkatu 15.

Lunches will be offered in the restaurant **Tilia**, in the T-building of the University. Here you can find the menu: https://www.semma.fi/en/restaurants/seminaarinmaki/restaurant-tilia/

The **poster session** will be held on Tuesday and Wednesday in the **ground floor** of Musica, next to the Auditorium.

Wi-Fi will be available during the conference (SSID: jyu-guest; login: cjya-5894). JYU also provides access to an eduroam network.

The **conference dinner** will be held at Savutuvan Apaja. We will take a cruise on the way to Savutuvan Apaja and a bus back to the city center.

How to get to Musica?

The Musica building is located in the Seminaarinmäki Campus of the University of Jyväskylä. It is five blocks away from the city center. It is marked with an M in the map below. Here you can find an interactive version of this map, which allows you to visualize outdoor activities, cycling routes, bus routes, restaurants, etc.: https://navi.jyu.fi/building/m11316

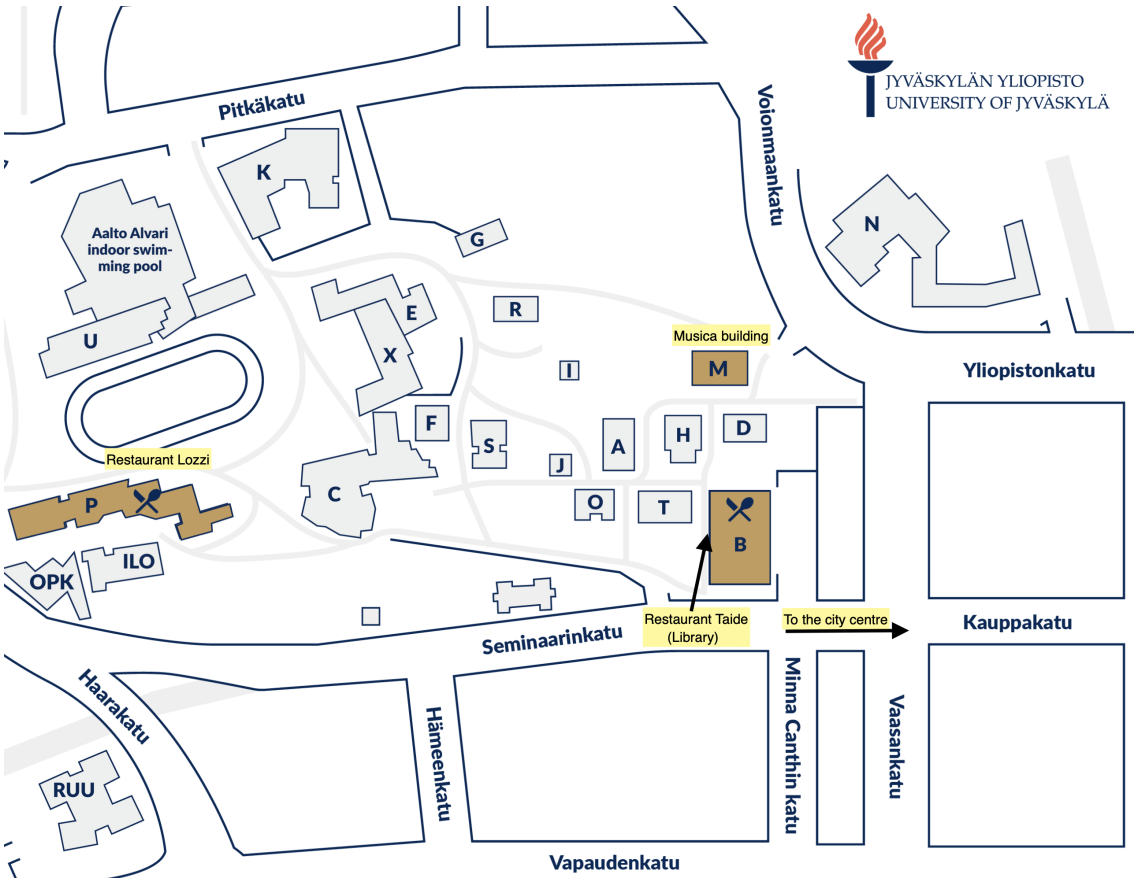
How to get to the university restaurants?

We can have lunch at either Restaurant Taide or Restaurant Lozzi. Taide is located in the university library, just a 100-meter walk from the Musica building. Lozzi is about 500 meters from Musica and is also worth visitingit's housed in a building designed by the renowned architect Alvar Aalto.

All three locations are marked on the map below.

Menus

Taide menu
Lozzi menu


JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ
Pitkäkatu
Voionmaankatu
Yliopistonkatu
Kauppakatu
Seminaarinkatu
Haarakatu
Hämeenkatu
Minna Canthin katu
Vaasankatu
Vapaudenkatu
Aalto Alvari indoor swimming pool
Restaurant Lozzi
Musica building
Restaurant Taide (Library)
To the city centre
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CENTRE OF EXCELLENCE IN MUSIC, MIND, BODY AND BRAIN

MUSICONNECT

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