Oral | Motor, Music

Sun. Oct 19, 2025 9:00 AM - 10:30 AM JST | Sun. Oct 19, 2025 12:00 AM - 1:30 AM UTC Venue 4(KOMCEE W B1F-011)

[O7] Oral 7: Motor, Music

Chair:Ségolène M. R. Guérin(Université du Littoral Côte d'Opale)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[O7-01]

Phase-dependent encoding of motor memory

*Yuto Makino[1], Masaya Hirashima[1] (1. National Institute of Information and Communications Technology (Japan))

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[O7-02]

Mapping Time and Space in Social Interactions with the Mirror and Rock-Paper-Scissor Games

*Julia Ayache[1,2], Marta Bieńkiewicz[2], Simon Pla[2], Pierre Jean[2], Alexander Sumich[1,3], Nadja Heym[1], Benoit G. Bardy[2] (1. NTU Psychology, Nottingham Trent University, Nottingham (UK), 2. EuroMov Digital Health in Motion, Univ. Montpellier IMT Mines Alès, Montpellier (France), 3. Department of Psychology, Auckland University of Technology, Auckland (New Zealand))

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[O7-03]

Sharing Timing in Physical and Virtual Spaces

*Julien Laroche[1], Julia Ayache[1], Marco Coraggio[2], Angelo di Porzio[2], Francesco de Lellis[3], Anna Katharina Hebborn[4], Andreas Panayiotou[5], Lyam Pepin[6], Panayiotis Charalambous[5], Simon Pla[1], Pierre Jean[1], Mario di Bernardo[2,3], Didier Stricker[4], Benoît Bardy[1] (1. EuroMov DHM, Univ. Montpellier, IMT Alès (France), 2. Scuola Superiore Meridionale (Italy), 3. Univ. Napoli ”Federico II” (Italy), 4. German Research Center for Artificial Intelligence (Germany), 5. CYENS (Cyprus), 6. Univ. Paul Valery Montpellier, (France))

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[O7-04]

Juggling on the Moon: Adaptation of complex motor skills to simulated low-gravity enabled changes in tempo

*John Rehner Iversen[1], Akilesh Sathyakumar[1], Hyeonseok Kim[2], Makoto Miyakoshi[2], Wanhee Cho[3], Hirokazu Tanaka[4], Takahiro Kagawa[5], Makoto Sato[3], Scott Makeig[7], Hiroyuki Kambara[6], Natsue Yoshimura[3] (1. McMaster University (Canada), 2. Cincinnati Children's Hospital Medical Center (United States of America), 3. Institute of Science Tokyo (Japan), 4. Tokyo City University (Japan), 5. Aichi Institute of Technology (Japan), 6. Tokyo Polytechnic University (Japan), 7. University of California San Diego (United States of America))

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[O7-05]

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

*Ségolène M. R. Guérin[1,2], Emmanuel Coulon[2], Tomas Lenc[2,3], Rainer Polak[4], Peter Keller[5], Laurie Gallant[2], Antoine Boveroux[2], Sylvie Nozaradan[2] (1. URePSSS, Université du Littoral Côte d'Opale (France), 2. Institute of Neuroscience (IoNS), Université Catholique de Louvain (UCLouvain) (Belgium), 3. Basque Center on Cognition, Brain, and Language (BCBL) (Spain), 4.

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10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[O7-06]

Evidence for neural categorization of rhythm in human newborns

*Francesca M. Barbero[1], Tomas Lenc[1,2], Alban Gallard[3], Nori Jacoby[4,5], Rainer Polak[6,7], Arthur Foulon[3], Sahar Moghimi[3], Sylvie Nozaradan[1,8] (1. Institute of Neuroscience (IoNS), University of Louvain (UCLouvain), 1348 Louvain-la-Neuve (Belgium), 2. Basque Center on Cognition, Brain and Language (BCBL), Donostia-San Sebastian (Spain), 3. Groupe de Recherches sur l'Analyse Multimodale de la Fonction Cérébrale (GRAMFC, Inserm UMR1105), Université de Picardie, 80054 Amiens (France), 4. Computational Auditory Perception Group, Max Planck Institute for Empirical Aesthetics, Grüneburgweg 14, 60322 Frankfurt am Main (Germany), 5. Department of Psychology, Cornell University, Ithaca, NY 14853 (United States of America), 6. RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo (Norway), 7. Department of Musicology, University of Oslo (Norway), 8. International Laboratory for Brain, Music and Sound Research (BRAMS), Montreal (Canada))

Phase-dependent encoding of motor memory

*Yuto Makino[1], Masaya Hirashima[1]

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Motor behaviors are highly flexible across temporal and spatial scales. For example, when writing a letter, its geometric pattern is preserved despite variations in scale and speed (Viviani & Terzuolo, 1980). Such flexibility cannot be fully explained by internal representations based on movement states (Sing et al., 2009) or absolute time. Instead, the brain may rely on a more abstract representation that captures the temporal progression relative to its overall structure. Here, we propose the existence of phase-dependent motor primitives, where phase defines the normalized temporal position within a movement. In Experiment 1, participants adapted to an S-shaped force during an 8 cm (or 16 cm) reach, where the force reversed midway. They then produced similar force patterns in untrained 16 cm (or 8 cm) reaches. This generalization cannot be explained by movement states alone, suggesting the involvement of an abstract feature such as phase, which, in a single reach, is difficult to separate from acceleration. In Experiment 2, we dissociated phase from acceleration using a double-reach task. Opposing force fields were applied to either the first or second half of the overall movement. If the same motor primitives had been engaged in both halves, interference would be expected. However, participants successfully learned both fields, suggesting a separation of motor primitives between the first and second halves of the movement. In Experiment 3, we used a button–reach–button task to dissociate the reach phase within the overall movement sequence from the ordinal position of the reach itself. Participants learned opposing force fields depending on phase (at one-quarter vs. three-quarters in the overall movement). Since the reach was always the second action, the observed separation of motor primitives must be attributed to its phase within the overall sequence. These results suggest that internal models are organized according to phase within a unified motor sequence.

Keywords: Motor learning, Phase , Motor primitives

Mapping Time and Space in Social Interactions with the Mirror and Rock-Paper-Scissor Games

*Julia Ayache[1,2], Marta Bieńkiewicz[2], Simon Pla[2], Pierre Jean[2], Alexander Sumich[1,3], Nadja Heym[1], Benoit G. Bardy[2]

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Introduction. During social interactions, individuals tend to fall into synchrony (i.e., temporal matching) and imitate each other (i.e., spatial matching). While synchrony and imitation have attracted considerable attention due to their association with affiliative tendencies, they are seldom investigated simultaneously. Furthermore, although often regarded as markers of “successful” interactions, being temporally and spatially matched is not always optimal for “efficient” interactions. Consequently, this study investigated the association between synchrony and imitation using two social interaction games known to elicit these behaviors: the Mirror and Rock-Paper-Scissors (RPS) games.

Methods. Twenty-six dyads completed the Mirror and the RPS games under three visual coupling conditions: (i) OPEN, where both participants could see each other; (ii) MIXED, where only one participant could see the other; and (iii) CLOSED, where neither could see the other. The OPEN and CLOSED conditions were counterbalanced across dyads to control for order effects. Movements were recorded using infrared cameras, and participants completed self-report measures of affective state and self-other overlap before and after each interaction

Results. Visual coupling influenced emotional arousal, perceived self-other overlap, and behavioral matching. When participants could see each other, they reported feeling more connected and aroused, and demonstrated increased spatiotemporal alignment in both the Mirror and RPS games. Notably, behavioral synchrony during the Mirror Game predicted imitation tendencies in the subsequent RPS game.

Conclusion. These findings suggest a robust link between temporal and spatial alignment, even in competitive contexts. Participants who exhibited stronger behavioral synchrony in the Mirror Game were more likely to adopt similar RPS strategies, indicating that coordinated movement may foster shared cognitive patterns. Ongoing analyses of EEG synchrony and inter-individual differences may further elucidate the neural and dispositional underpinnings of this association between acting and thinking together.

Keywords: Behavioral Matching, Synchrony, Imitation, Mirror Game, Rock-Paper Scissor Game

Sharing Timing in Physical and Virtual Spaces

*Julien Laroche[1], Julia Ayache[1], Marco Coraggio[2], Angelo di Porzio[2], Francesco de Lellis[3], Anna Katharina Hebborn[4], Andreas Panayiotou[5], Lyam Pepin[6], Panayiotis Charalambous[5], Simon Pla[1], Pierre Jean[1], Mario di Bernardo[2,3], Didier Stricker[4], Benoît Bardy[1]

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Communicating and connecting with others relies on fine-tuned embodied coordination. Yet, as our social lives increasingly shift online where movement cues become impoverished, our ability to connect meaningfully is getting challenged. While Virtual Reality (VR) offers promising opportunities for embodied interaction in digital spaces, little is known about how to best capture, render and foster embodied coordination in this medium. Hence the ShareSpace project aims to better understand the constraints of virtual spaces on multi-agent embodied coordination, with the goal to optimize both motion capture and rendering.We report a series of studies on group movement coordination performed in both physical and virtual reality. In the first two studies, triads and quartets synchronized arm movements and reported their experiences of social connection. Results show that the kinematic and social benefits of group synchrony observed in physical reality transfer to VR. However, while people accelerated their pace when synchronizing in physical settings, this tendency was reversed in VR, showing how digital constraints can alter coordination strategies. In a subsequent VR study, we restricted participants’ field of view to examine their interaction strategies, and in some cases, replaced one human partner with an adaptive artificial agent. This agent shared a similar appearance but was driven by a cognitive architecture optimized for group coordination. The presence of the adaptive agent led to an increase in movement pacing, suggesting that it could counteract the decelerating effects of digital interaction on collective kinematics. Most participants did not detect the agent swap yet reported feeling less socially connected to partners who had been replaced. These findings show the critical role of subtle kinematic cues in social coordination and offer new guidelines to design hybrid digital spaces that support authentic group interaction.

Keywords: Group synchronization, Virtual Reality, Social connection, Artificial Agent

Juggling on the Moon: Adaptation of complex motor skills to simulated low-gravity enabled changes in tempo

*John Rehner Iversen[1], Akilesh Sathyakumar[1], Hyeonseok Kim[2], Makoto Miyakoshi[2], Wanhee Cho[3], Hirokazu Tanaka[4], Takahiro Kagawa[5], Makoto Sato[3], Scott Makeig[7], Hiroyuki Kambara[6], Natsue Yoshimura[3]

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Many commonly used rhythmic timing tasks can be easily varied in tempo, revealing important scaling laws of timing behavior and aiding learning. In contrast, it is more challenging to vary the tempo of real-world physical tasks like three-ball juggling. To address this, our collaborators have developed a realistic VR visuo-haptic simulation of juggling under reduced gravity using a novel force-generating input device to realistically simulate the physics and proprioception of ball throwing and catching (Kambara et al, *Proc IDW*, 2022). The setup enables the experimental modification of juggling tempo in a way that is not possible in physical settings. Our prior work has shown that juggling training in reduced gravity can enhance skill acquisition in novices, potentially by facilitating the learning of bimanual motor sequencing. (Cho et al., *IEEE VRW*, 2025). Here we shift focus to expert jugglers adapting to slow tempo juggling to test hypotheses about temporal scaling in motor control: proportional scaling vs. constant hold time (which relate to the continuous vs. discrete timing duality in the rhythmic timing literature). We measured motor kinematics (hand trajectories and timing of ball catches and throws) in relation to ball trajectory to describe how these scale with juggling tempo manipulated by changing simulated gravity. Our initial results (though n=2) are that a third alternative is suggested: jugglers attempt to increase tempo in low gravity by using shorter throws. This behavior may reflect VR-specific constraints, such as narrower field of view and less realistic proprioceptive feedback, prompting design improvements including pacing stimuli and visual apex targets to encourage slower juggling. This behavioral foundation supports planned neural studies of temporal scaling of neural dynamics using new methods for movement artifact rejection (Kim et al., *Sensors*, 2023; *J Neur Meth*, 2025).

Keywords: motor learning, adaptation, timing, rhythm, tempo, juggling

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

*Ségolène M. R. Guérin[1,2], Emmanuel Coulon[2], Tomas Lenc[2,3], Rainer Polak[4], Peter Keller[5], Laurie Gallant[2], Antoine Boveroux[2], Sylvie Nozaradan[2]

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Music naturally induces human movement through its rhythmic structure. Conversely, synchronised body movement can shape rhythm perception –a short-term effect that is likely influenced itself by lifelong cultural exposure. Yet, direct experimental evidence for both short- and long-term modulation of rhythm processing through movement remains limited.
To address this, we present a registered report using electroencephalography (EEG) and hand-clapping responses to a highly syncopated, metrically ambiguous rhythm derived from West/Central African musical traditions (N = 80). These neural and behavioural responses were recorded separately in participants from West/Central Africa and Western Europe before and after a body-movement session involving stepping and clapping to a cued beat (either three- or four-beats meter, the latter concurring with original music-cultural conventions).
African participants exhibited a significant short-term effect, clapping more consistently and in closer alignment with the beat as cued in the body-movement session. They also more reliably interpreted the rhythm in line with cultural conventions, both before and after movement. In contrast, European participants showed no significant short-term movement effect. A sibling study was then conducted on an additional Western cohort (N = 40), where the body movement session was replaced by watching audiovisual clips of individuals performing the same body movement as in the first study, while remaining still. In contrast with Study 1, behavioural responses to the cued beat were found to be significantly more consistent after the training session, suggesting that multisensory inputs, possibly activating motor representation without actual movement production, can elicit a short-term effect even when production of actual movement does not.
Finally, inconsistencies between neural and behavioural data in both studies suggest that a brief training session alone may not robustly stabilise a beat interpretation that can be automatically reactivated in neural activity after the movement cessation, particularly in response to a complex, syncopated rhythm. Nonetheless, when participants are compelled to move to such a rhythm, they can draw on learnt beat–rhythm association to guide movement timing.

Keywords: cross-cultural, EEG, frequency tagging, rhythmic entrainment, body movements

Evidence for neural categorization of rhythm in human newborns

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Humans show an outstanding capacity to perceive, learn, and produce musical rhythms. These skills rely on mapping the infinite space of possible rhythmic sensory inputs onto a finite set of internal rhythm categories. What are the brain processes underlying rhythm categorization? One view is that rhythm categories stem from neurobiological predispositions constraining internal representations of rhythmic inputs. However, a growing body of work suggests that rhythm categorization is plastic, open to be shaped by experience over the course of life. To tease apart the relative contributions of neurobiological predispositions and experience in rhythm categorization, we measured neural responses to rhythm in healthy full-term human neonates, capitalizing on their minimal post-natal experience.
Scalp electroencephalography (EEG) was recorded from newborns while they were exposed to 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.
Preliminary results indicate significant rhythm categorization in neonates, with categories encompassing the 1:1 and 2:1 integer ratio rhythms, and with a categorical structure similar to the neural and behavioral responses of adults. These findings suggest that internal representations of rhythm may be biased towards categorical structure by neurobiological properties already in place at birth. This study thus paves the way to further investigate the neural processes by which these internal categories would be further shaped by individual and cultural experience, leading to the diversity in music perception and behaviors observed worldwide.

Keywords: musical behavior, development, rhythm perception, electroencephalography