UNIVERSITY OF BIRMINGHAM

Advances in Motor Learning II

Conference Brochure

11 – 12 December 2025
Edgbaston Park Hotel, Birmingham

Contents

Conference Welcome

Dear Colleagues,

Welcome to **Advances in Motor Learning II** at the University of Birmingham, UK! Following the success of our 2022 edition at the University of Twente, NL, chaired by Russell Chan and Willem Verwey, we return with a fresh, dynamic programme exploring how motor skills are acquired, adapted and restored. This research transcends purely curiosity-driven endeavour. It holds critical relevance in today's fast-evolving neurotechnological and neurorehabilitation landscape, particularly as the demographic changes and the associated demand for advanced neurological rehabilitation is projected to climb dramatically over the next decades.

Over the two days, we will dive into cutting-edge findings across four key themes, with keynotes, talks, posters and discussion panels dedicated to each of the **conference themes interfacing with motor learning**:

- **Plasticity**: Opportunities and limitations of harnessing neural plasticity for movement rehabilitation and performance.
- **Interference**: Cognitive, behavioural and neurophysiological interventions with motor learning.
- **Disorders**: Challenges and advances in understanding and treating motor learning disorders
- **Consolidation**: Rethinking the processes that stabilises and sustain long-term motor learning.

The themes are inherently interconnected, allowing common questions and discussions to emerge across them. This intentional overlap is designed to deepen the discourse, as well as spark new directions and collaborations.

We are grateful for the generous support that makes this event possible. We are thrilled to host the **Excellence in Motor Learning and Ethical Design Awards**, with four £400 prizes recognising outstanding poster contributions, generously donated by **Meta Reality Labs**. Our thanks go to our Silver Sponsor **Delsys**, our principal exhibitor, along with **Intuitive Surgical**, and University of Birmingham academic organisations **- Centre for Human Brain Health** and the **College of Life and Environmental Sciences**, as well as our external funding partners, including the **UKRI Future Leaders Fellowship** and the **EPSRC/MRC N-CODE Network**. Early career researchers will have the opportunity to spearhead a review of the conference highlights to the **Journal of Motor Learning and Development**.

The University of Birmingham, a member of the Russell Group, combines world-class research with a rich cultural presence. On campus, attendees can explore institutions like the Lapworth Museum of Geology (showcasing 4.5 billion years of Earth's history) and the Elgar Concert Hall. The beautiful Winterbourne House and Garden next to campus also provides an Edwardian escape right next to the conference venue.

Birmingham itself is a city of innovation, diversity and culture. As a powerhouse of the Industrial Revolution, earning the nickname "City of a Thousand trades" and boasts more miles of canals than Venice. This rich history has shaped one of the UK's most diverse cities, where over 180 nationalities contribute to a vibrant culture, particularly evident in the world-renowned cuisine across the city. Coincidentally, Birmingham is also home to **exceptional real-world examples of motor learning and skill mastery -** the City of Birmingham Symphony Orchestra, the Birmingham Royal Ballet, and the Aston Villa and Birmingham City football clubs.

Thank you for joining us! We look forward to two days of stimulating presentations and discussions, and shared progress in our community's ongoing exploration of motor learning.

With best wishes,

The Advances in Motor Learning II Organising Committee

Conference Chair:
Katja Kornysheva PhD

Associate Professor in Human Neuroscience,
UKRI Future Leaders Fellow
Centre for Human Brain Health
School of Psychology, University of Birmingham

Conference Panel:
Arnaud Boutin,
Russell Chan,
Maarten Immink,
Katja Kornysheva,
Willem Verwey
Coen Zandvoort (ECR member).

About

Advances in Motor Learning II, taking place on the 11-12 December 2025 at the Edgbaston Park Hotel is a two-day, single-track conference bringing together leading experts in cognitive neuroscience, psychology, clinical practice, and neurorehabilitation.

Attendees will explore cutting-edge developments in motor learning, spanning diverse methodologies and levels of analysis - from behavioural paradigms to advanced neuroimaging and brain stimulation techniques.

This year's conference brings together leading voices to explore four themes - plasticity, interference, disorders, and consolidation. Through keynote lectures, invited presentations, poster sessions, and panel discussions, we aim to foster critical dialogue and future research initiatives in this field.

We are pleased to acknowledge the generous support of UK Research and Innovation (UKRI) Future Leaders Fellowship, the College of Life and Environmental Sciences and our industry sponsors.

We look forward to welcoming you to an engaging and thought-provoking meeting.

Edgbaston Park Hotel and Conference Centre

Donor & Poster Prizes

We are delighted to announce four poster prizes: the Reality Labs Excellence in Motor Learning and Ethical Design Award (£400 each), generously donated by Meta Reality Labs.

Silver Sponsors

Bronze Sponsor

Key Information

Conference Address
Lloyd Suite
Edgbaston Park Hotel
53 Edgbaston Park Rd
Birmingham
B15 2RS

The Lloyd Suite is located opposite the hotel entrance.

Travel Information
Please visit the event travel information for more details on how to get to the conference.
Please note that we have a train station on campus (University Station – Birmingham) which is only a short walk (8-10 minutes) from Edgbaston Park Hotel.

Parking Information
Car parking is free when visiting Edgbaston Park Hotel. The car park is located outside the entrance of the hotel and additional free parking is available on the ground floor only of the adjacent multi-storey car park. Please ensure you provide your car registration on entry at the hotel reception.

Conference Registration and Information Desk
Members of the University of Birmingham Event Management Team will be on hand to register you for the conference and for any questions during the day.
The registration and information desk will be open:

Thursday 11 December, 08:30 – 17:00
Friday 12 December, 08:30 – 17:00

Conference Dinner
Thursday 11 December, 19:00 – 21:30

The Vaults
The Exchange
3 Centenary Square
Birmingham
B1 2DR

Please see online for more details on The Exchange and the Conference Dinner.

Additional Information

What to do on Campus

The University campus offers a wide range of attractions for you to enjoy during your stay, all of which boast great history and culture.

Lapworth Museum of Geology

Enabling visitors to explore life over the past 3.5 billion years, the Lapworth Museum showcases exceptional objects from one of the UK's most outstanding geological collections, with state-of-the-art galleries and a range of innovative and interactive exhibits - all completely free of charge. From rocks and fossils to volcanoes, earthquakes, and even dinosaurs, the Museum captures the imagination of all ages.

Opening Times:
Monday to Friday, 10:00 - 16:00
Saturday and Sunday, 12:00 - 17:00

Winterbourne House and Garden

Restored to its Edwardian Arts and Craft splendour, Winterbourne House is a unique heritage attraction set within seven acres of beautiful botanic gardens. Winterbourne is a hidden gem, home to beautiful antiques and over 6,000 plant species from around the world. Wander along the woodland walk, stroll through the hazelnut tunnel, cross the 1930's Japanese Bridge or simply soak up the tranquillity of this perfectly English Edwardian home. Located on Edgbaston Park Road, a few minutes' walk from Edgbaston Park Hotel.

Opening Times:
Monday to Sunday 10:30 – 16:00 (last entry 30 minutes before closing)
Delegates are entitled to a 50% discount on the admission fee.

University of Birmingham Blue Plaque and Sculpture Trails

There have been many influential achievements by brilliant men and women who have worked at the University of Birmingham since its earliest days. The Blue Plaques highlight these special achievements and celebrate those who have helped to shape our heritage as a research university.
Download the guide here.

Campus Sculpture Trail

The Campus Sculpture Trail allows you to explore the range of styles, subjects and shapes of sculpture on the University's Edgbaston campus. The Faraday Bronze Sculpture was commissioned to mark the centenary of the University of Birmingham's Royal Charter; this is located near the train station.
Visit the website for more information.

Want to explore Birmingham further?

Please see our Explore Birmingham page on the website.

Thursday 11 December 2025: Neural Plasticity & Interference

Time	Session
08:30 – 09:30	Registration and Refreshments
09:30 – 09:45	Welcome - Katja Kornysheva (University of Birmingham, UK)
	Session 1: Neural Plasticity
09:45 – 10:45	**Keynote 1:** Tamar Makin (University of Cambridge, UK) **Sensorimotor skill learning outside the body**
10:45 – 11:45	**Individual Talks:** Ken Valyear (Bangor University, UK) Sara Hussain (University of Iowa, USA) Catharina Zich (University of Oxford, UK) Session Chair: Katja Kornysheva (University of Birmingham, UK)
11:45 – 12:15	Refreshment Break and Networking
12:15 – 12:45	**Panel Discussion:** Harnessing Neural Plasticity for Rehabilitation and Performance
12:45 – 13:30	Lunch - Served in the hotel restaurant (main building)
	Session 2: Interference
13:30 – 14:30	**Keynote 2:** Friedhelm Hummel (EPFL, CH) **Stimulating the Mind: Non-Invasive Neuromodulation to enhance Motor and Cognitive Functions**
14:30 – 15:30	**Individual Talks:** Joseph Galea (University of Birmingham, UK) Maarten Immink (Flinders University, AUS) Willem Verwey & Russell Chan (Twente University, NL) Session Chair: Arnaud Boutin (Université Paris-Saclay, FR)
15:30 – 16:00	**Panel Discussion:** Interference – Challenges and Frontiers
16:00 – 17:00	Poster Session with refreshments
19:00 – 21:30	Conference Dinner

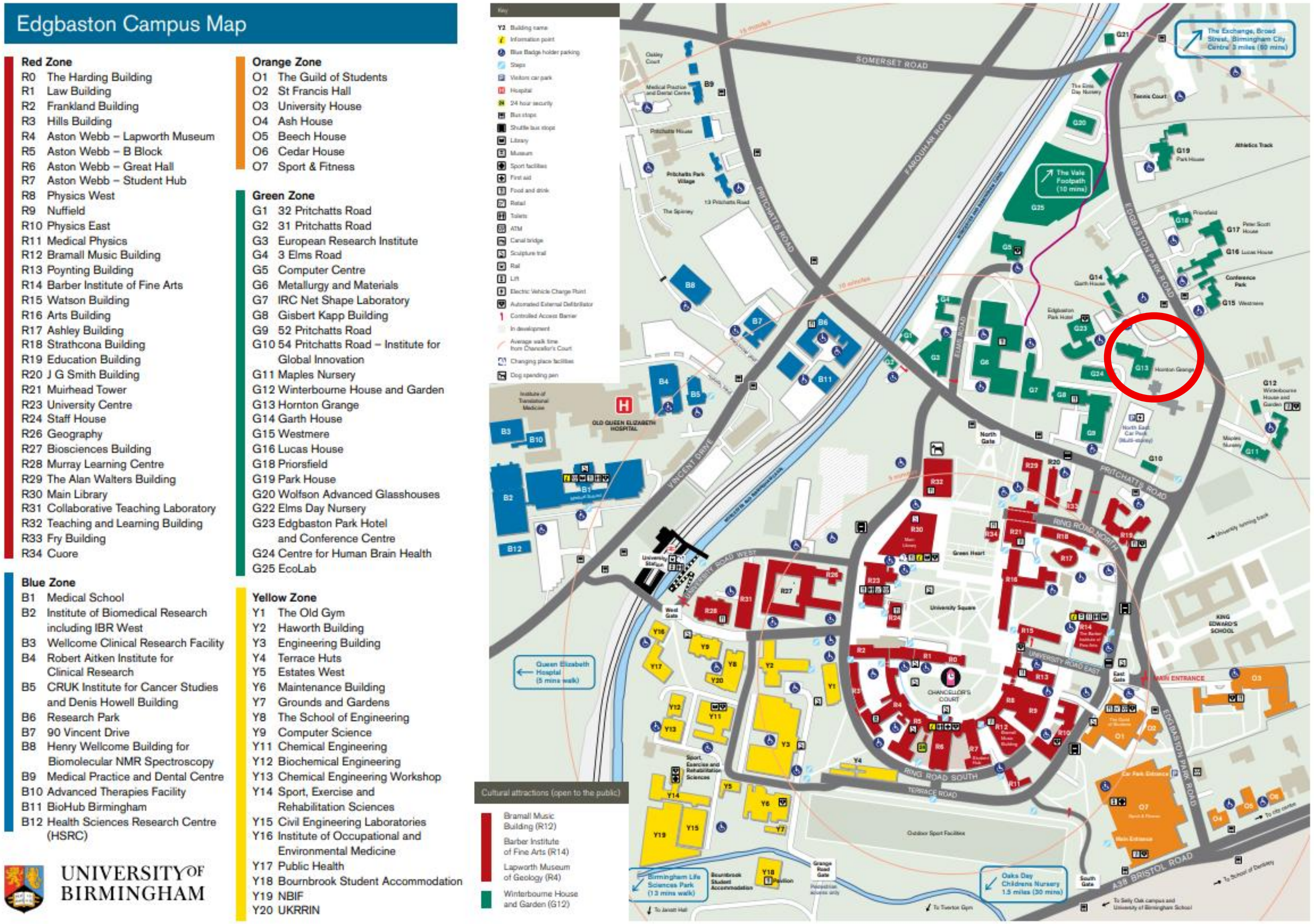
Friday 12 December 2025: Disorders & Consolidation

Time	Session
08:30 – 09:00	Refreshments and Networking
	Session 3: Disorders
09:00 – 10:00	**Keynote 3:** Anna Sadnicka (University College London, UK) **Precision Disrupted: Rethinking the Neural Basis of Task-Specific Dystonia**
10:00 – 11:00	**Individual Talks:** Maria Herrojo Ruiz (Goldsmiths University of London, UK) Matthew Weightman (University of Oxford, UK) Marit Ruitenberg (Leiden University, NL) Session Chair: Maarten Immink (Flinders University, AUS)
11:00 – 11:30	Refreshment Break
11:30 – 12:00	**Panel Discussion:** Challenges and Advances in Treating Motor Learning Disorders
12:00 – 13:00	Lunch - Served in the hotel restaurant (main building)
	Session 4: Consolidation
13:00 – 14:00	**Keynote 4:** Genevieve Albouy (University of Utah, US) **Role of the Hippocampus in Wake- and Sleep-Related Motor Memory Consolidation**
14:00 – 15:00	**Individual Talks:** Arnaud Boutin (Université Paris-Saclay, FR) Simon Steib (University of Heidelberg, GER) Pierre Vassiliadis (EPFL, CH and University College London, UK) Session Chair: Willem Verwey (Twente University, NL)
15:00 – 15:30	**Panel Discussion:** Rethinking Consolidation in Long-Term Motor Learning
15:30 – 16:30	Poster Session with refreshments
16:30 – 17:00	**Poster Prizes and Closing Ceremony**

Campus Map

[An interactive campus map can also be viewed online]

The conference will take place in the Lloyd suite, in the Hornton Grange Building at the Edgbaston Park Hotel (G13 – Green Section)



Campus Map

Edgbaston Park Hotel and Conference Centre

Speakers - Neural Plasticity

Tamar Makin, University of Cambridge

Biography: Tamar Makin is a Professor of Cognitive Neuroscience at the MRC Cognition and Brain Sciences Unit at Cambridge University and the leader of the Plasticity Lab www.plasticity-lab.com. Her main interest is in understanding how our body representation changes in the brain (brain plasticity). Her primary model for this work is studying hand function and dysfunction, with a focus on how we could use technology to increase hand functionality in able and disabled individuals at all ages. Tamar was awarded several career development fellowships to establish her research programme on brain plasticity at the University of Oxford, first as Research Fellow (2009) and later as a Principle Investigator (2014). She joined the faculty of UCL in 2016 where she became a Professor of Cognitive Neuroscience (2019) and moved to Cambridge in 2022 to continue her work. She has been supported by the European Research Council (Starting and Consolidator Grants; deferred to UKRI), the Wellcome Trust (Henry Dale and Senior Research Fellow), the UK Engineering and Physical Sciences Research Council, in addition to the UK Medical Research Council.

Sensorimotor skill learning outside the body

Motor augmentation devices, such as supernumerary robotic limbs, promise to enhance human motor capabilities, but their success hinges on users' ability to generalise learned skills across tasks and contexts. We trained participants over multiple time scales to use an extra robotic thumb (Third Thumb, Dani Clode Design), worn on the right hand and controlled via the toes.

Participants demonstrated broad somatosensory and motor skills and were able to generalise their skill across tasks, body postures, and even when either the actuator or controller was remapped to a different body part, suggesting the development of flexible, effector-independent motor representations.

Furthermore, participants showed reduced cognitive demands and an increased sense of agency and somatosensory embodiment over the device, which also associated with neural embodiment of the device in primary somatosensory cortex. Despite substantial learning, generalisation, and increased embodiment, participants did not preferentially choose to use the Third Thumb when given the option during free-choice tasks.

These findings suggest that neither extensive generalisation nor embodiment alone are sufficient for widespread adoption of augmentation technologies, highlighting the importance of human factors in their real-world integration.

Ken Valyear, Bangor University

Altered digit maps in human primary somatosensory cortex following hand nerve repair.

Hand nerve transection injuries precipitate a variety of reorganisational changes in both the peripheral and central nervous systems. Surgical repair restores the continuity of severed nerves, yet regenerating fibres establish new connections without topographical guidance, rearranging the structure of inputs from the hand to the brain. In non-human primates, forelimb nerve transection and repair dramatically alters the otherwise orderly and highly conserved organisation of the digit maps in primary somatosensory cortex. These changes are presumed to occur in humans and to have meaningful functional implications for patient recovery.

In this talk, I discuss our recent project testing these assumptions. Our findings provide evidence for altered digit maps following nerve repair in humans, bridging results from animal models. Nonetheless, whether these changes impact patient recovery remains unclear. I will suggest how future work may help disentangle peripheral from central drivers of altered digit maps and clarify their potential impact on patient outcomes.

Sara Hussain, University of Iowa

Peaks or troughs? Untangling mu phase-dependent mechanisms of motor sequence learning

The sensorimotor mu rhythm coordinates neuronal spiking, corticospinal output, and susceptibility to long-term potentiation-like plasticity. Our previous work showed that TMS interventions delivered to M1 during mu trough but not peak phases significantly enhanced offline motor sequence learning, suggesting that the neurophysiological mechanisms supporting motor sequence learning fluctuate cyclically with the mu rhythm. In this talk, I will discuss a recent study (Suresh et al. 2025, Journal of Neurophysiology) where we directly tested this possibility using the serial reaction time task and mu phase-dependent measures of corticospinal plasticity. Surprisingly, findings revealed that sequence-specific learning elicited significant mu phase-specific corticospinal plasticity which correlated with learning magnitude. Results directly challenge prior assumptions that learning-related plasticity processes are restricted to mu trough phases and provide first direct evidence that motor sequence learning recruits mu phase-dependent neurophysiological processes in the human brain.

Catharina Zich, University of Oxford

Movement-related beta activity and plasticity in motor learning and stroke recovery

Movement-related beta activity (beta ERD/ERS) is tightly linked to motor learning in healthy adults, reflecting experience-dependent plasticity. After stroke, beta modulation is consistently reduced across acute, subacute, and chronic stages, yet its gradual restoration tracks recovery-related plasticity. Building on this rationale, integrating beta activity with clinical and structural measures improves prediction of early post-stroke outcomes, highlighting its value as a functional biomarker. Motivated by these findings, we tested whether beta activity can be systematically modulated. Using a kinematics-triggered closed-loop stimulation protocol designed to boost post-movement beta-ERS, we demonstrate modulation of beta activity in healthy adults, with stimulation-induced changes relating to behaviour. I will also present the ongoing second-phase study extending this approach to chronic stroke survivors.

Speakers - Interference

Friedhelm Hummel, EPFL

Biography: Prof. Friedhelm Hummel, MD, is a trained neurologist and translational neuroscientist, with more than 20 years of experience in clinical neurology, neuroscience and neuroengineering.
Since 2016, he is Full-Professor at EPFL and Director of the Defitech Chair of Clinical Neuroengineering in the Neuro-X Institute (INX), and Adjunct Professor at the University Hospital Geneva (HUG).
Scientific interests are in the development of neurotechnologies to enhance human behavior with a strong translational focus. He pioneered e.g., the application of non-invasive brain stimulation to enhance stroke recovery. Further interests lie in the understanding of motor and cognitive behavior during healthy aging and after stroke, traumatic brain injury or dementia using multimodal systems neuroscience and in neuro-technology as innovative interventional strategies to enhance impaired behavior, adaptation to and recovery from neurological and mental disorders. Currently, he pioneered the human application of non-invasive deep brain stimulation and demonstrated first successful human proof-of-concept.

Stimulating the Mind: Non-Invasive Neuromodulation to enhance Motor and Cognitive Functions

Non-invasive brain stimulation techniques represent powerful tools for enhancing motor and cognitive functions by modulating neural activity safely and effectively. This talk will provide an overview of current non-invasive neuromodulatory approaches, emphasizing their potential for facilitating motor learning and enhancing memory functions. Key methods, including transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS), will be discussed, along with a particular emphasis on the innovative transcranial temporal interference stimulation (tTIS), an emerging technology (e.g., Wessel *et al.* 2023, Vassiliadis *et al.* 2024). The talk will highlight recent groundbreaking evidence demonstrating the unique capabilities of tTIS to non-invasively stimulate deep brain structures with enhanced spatial precision in humans, offering significant advantages over traditional methods. Focus will be placed on the underlying neurophysiological mechanisms of tTIS, practical application strategies, and its promising potential implications for rehabilitation, motor learning, and memory consolidation in healthy and pathological conditions. Finally, future directions and challenges in optimizing neuromodulation protocols, particularly with advanced techniques like tTIS, for targeted motor and cognitive improvements will be explored.

Joseph Galea, University of Birmingham

Reward-Driven Motor Improvements are Resistant to Interference from Brain Stimulation, Drugs, Ageing and Disease

Reward has a powerful ability to enhance motor behaviour, allowing individuals to perform actions with greater speed and accuracy. Our research shows that reward improves motor performance through multiple error-reduction mechanisms -specifically, by increasing feedback correction and reducing motor noise. These mechanisms enable individuals to move faster without sacrificing precision. To better understand the neural basis of this effect, we conducted a series of experiments designed to disrupt it. We used inhibitory transcranial magnetic stimulation (TMS) over key brain areas involved in motor control -the primary motor cortex, supplementary motor area and ventromedial prefrontal cortex- but found no reduction in the reward-induced improvements in motor performance. Similarly, administering the dopamine antagonist haloperidol had no effect. Remarkably, the benefits of reward remained strong even in older adults and stroke patients. Together, these findings demonstrate that reward has a remarkably robust influence on motor performance. Its effects are not easily disrupted by external interventions such as brain stimulation or pharmacological manipulation, nor by internal changes such as ageing or brain injury. This underscores the resilience and potency of reward as a motivator for enhancing motor function.

Maarten A. Immink, Flinders University

Meditation, motor learning, and aging: From context preservation to contextual integration

Age-related declines in cognitive function and motor sequence learning can limit functional independence in older adulthood. Structural and functional neural changes, including reduced processing speed, diminished working memory, and excessive cognitive control, may constrain the acquisition of motor sequences. Mindfulness meditation has been shown to enhance motor sequence performance in younger adults and improve attention, executive function, and neural efficiency in older adults. This cross-sectional study examined whether healthy older adults with extensive mindfulness meditation experience demonstrate enhanced motor sequence performance compared with non-meditating peers, and whether any advantage reflects general performance differences or improved acquisition of sequence structure. Fifteen meditators (Mage = 59.8 ± 4.7 years; mean practice hours = 2,862) and 13 age-matched controls (Mage = 60.1 ± 5.7 years) completed a serial reaction time (SRT) task involving a 12-item second-order conditional sequence followed by a transfer block with a novel sequence. Meditators showed significantly higher mindfulness disposition on the Freiburg Mindfulness Inventory. Linear mixed models revealed no group differences in accuracy, but meditators responded significantly faster across all blocks. Learning rates did not differ between groups. Only meditators exhibited significant slowing at transfer, suggesting greater reliance on the trained sequence. Meditators also produced longer sequence chunks during some training blocks and showed higher sequence recall, supporting enhanced sequence learning. However, post-error slowing and reaction time autocorrelation did not provide convergent evidence of improved sequence representation. Overall, mindfulness meditation and higher dispositional mindfulness appear to be associated with faster choice response performance in older adults, but evidence for enhanced motor sequence learning is mixed, indicating that faster performance may not uniformly reflect stronger sequence representation development.

Willem B. Verwey, Twente University

The Three-Level System (TLS) architecture predicts fractal data patterns.

Based on behavioral evidence that information processing proceeds in serial stages, I recently proposed the Three-Level Systems (TLS) architecture that accounts for how the massively parallel operating brain can process information in stages, and also produce Short-Term Memory and Long-Term Memory (Verwey, 2025). The TLS architecture posits that the brain includes two evolutionarily older perceptual and motor systems that are linked by a third, flexible central processing system located in the evolutionarily more recent association cortex. I argue that this TLS architecture is consistent the idea that hierarchical control in the neural system may be indicated by fractal structures in motor performance data (Grosu et al., 2022). This idea is supported by findings presented in this session by Russell Chan.

Grosu, G. F., Hopp, A. V., Moca, V. V., Bârzan, H., Ciuparu, A., Ercsey-Ravasz, M., et al. (2022). The fractal brain: scale-invariance in structure and dynamics. Cerebral Cortex, 33(8), 4574-4605.

Verwey, W. B. (2025). The neural basis of cognitive processing: a review and a speculative architecture. Brain and Cognition, 189, 106351.

Russell W. Chan, Twente University

Fractal dynamics in the variability of centre of mass during dance learning provide insight to hierachical control processing.

The brain's hierarchical organization, as described by frameworks like the Three-Level Systems (TLS) architecture (Verwey, 2025), governs the control and learning of complex motor skills. A key question is to understand how these hierarchical control strategies are reflected in observable behavior, particularly in downstream movement variability. Fractal dynamics of motor performance offer a promising window to adaptive hierarchical processing (Grosu et al., 2022). Our study investigates this connection by applying fractal scaling analysis in the form of Hurst Exponents to the Centre of Mass (CoM) kinematics during the Dance-Discrete Sequence Performance (Dance-DSP) task. Our findings reveal a nuanced interplay: Faster performance was associated with increased fractal scaling during motor preparation. Conversely, during sequence execution, faster performance correlated with decreased fractal scaling. These results provide empirical support for the dynamic, context-dependent organization of hierarchical control, manifesting as distinct fractal signatures during different phases of skill performance.
Keywords: Motor sequence learning, Hierarchical control, Three-Level Systems, Fractal Dynamics, Movement Variability, Expertise, Biomechanics
Verwey, W. B. (2025). The neural basis of cognitive processing: a review and a speculative architecture. Brain and Cognition, 189, 106351.
Grosu, G. F., Hopp, A. V., Moca, V. V., Bârzan, H., Ciuparu, A., Ercsey-Ravasz, M., et al. (2022). The fractal brain: scale-invariance in structure and dynamics. Cerebral Cortex, 33(8), 4574-4605.

Speakers - Disorders

Anna Sadnicka, University College London

Biography: Anna is a clinical academic and lead of the Computational Movement Disorders Lab at UCL. The lab applies motor control theory and computational modelling to characterise the behavioural statistics of clinical phenomenology. Outputs from the lab's research directly informs neuromodulation and neurorehabilitation for patients. The lab is an interdisciplinary group, based at the Gatsby Computational Neuroscience Unit, a research centre dedicated to theoretical and computational neuroscience and the Department of Motor Neuroscience and Movement Disorders where participant data is collected purpose built labs next door to the hospital. As a Consultant Neurologist at the National Hospital for Neurology and Neurosurgery, Anna has a weekly movement disorders clinic and works within multidisciplinary groups that strive to take scientific insights directly into clinical care. Her research is funded by a Wellcome Trust award.

Precision Disrupted: Rethinking the Neural Basis of Task-Specific Dystonia

Task-specific dystonia is a movement disorder characterised by a painless, selective loss of motor control during the performance of a highly practised skill. This disorder is prevalent among writers, musicians, dancers, and athletes, and can often end the careers of affected individuals. Conventional disease models of dystonia fall short in explaining task-specific dystonia.
In this talk, I will present emerging evidence that task-specific dystonia arises from maladaptive engagement of compensatory mechanisms within an otherwise healthy motor system. I will detail how risk factors for task-specific dystonia can be stratified and mapped onto mechanisms of dysfunctional motor control, disrupting the representation and reproduction of skilled movement. Finally, I will highlight novel therapeutic avenues informed by this framework with a focus on motor retraining paradigms.

Maria Herrojo Ruiz, Goldsmiths University of London

Learning biases in performance anxiety

Performance anxiety (PA) is prevalent among skilled performers and can impair skilled performance in high-stakes settings, yet its mechanisms remain poorly understood. In a first study, we examined whether predisposition to PA biases motor-based learning from reward and punishment under varying task uncertainty. Across three experiments, 95 pianists learned hidden melody dynamics in large or reduced action spaces, which respectively introduced high or low task uncertainty. Using behavioural analysis, computational modelling, and electroencephalography, we observed that increasing PA levels were associated with faster reward learning in high uncertainty but faster punishment learning in low uncertainty, with these biases linked to reinforcement-driven modulation of motor variability and frontal theta activity.
Building on this, I will present results from a new study examining whether these uncertainty-dependent learning biases are amplified under high stakes. Forty-three pianists completed a within-subject reinforcement-learning task across four conditions (low vs high uncertainty × low vs high stakes). Preliminary findings show that uncertainty and stakes interact with PA: higher PA favours learning in low-uncertainty, low-stakes contexts, whereas lower PA facilitates learning in high-uncertainty, high-stakes settings. Notably, high-PA individuals, who showed poorer learning under high task uncertainty, partly benefited from high-stakes conditions in this setting, consistent with proposals that anxiety increases exploration to reduce uncertainty. These behavioural effects were accompanied by differences in reinforcement-driven motor-variability regulation and in alpha- and beta-band activity in the dorsal anterior cingulate cortex, prefrontal cortex, and, to a lesser extent, motor regions.

Matthew Weightman, University of Oxford

Sleep-dependent motor learning and functional recovery after stroke

Stroke remains a leading cause of long-term disability, with more than half of survivors experiencing persistent motor impairment. Although motor learning is fundamental to successful rehabilitation, a key component of this process - the consolidation of motor memories during sleep - remains underexplored in stroke recovery research.
Sleep plays an active role in strengthening newly learned motor skills by reactivating task-related neural patterns and stabilising fragile memories into more durable representations. Yet sleep disruption is highly prevalent after stroke and has been consistently linked to slower recovery and poorer functional outcomes. If practice drives learning during the day, sleep may be essential for turning that practice into lasting gains. Impaired sleep-dependent consolidation could therefore contribute to the suboptimal recovery seen in many patients. This talk will present previous work from our lab demonstrating associations between disrupted sleep and delayed functional improvement, alongside emerging findings from an ongoing clinical trial tracking longitudinal changes in sleep and motor recovery. I will highlight how sleep-dependent motor memory consolidation, measured using both subjective and objective sleep assessments, may shape rehabilitation trajectories and offer a promising target for future intervention.

Marit Ruitenberg, Leiden University

Movement and cognition in neurodegenerative disorders: A dynamic duo.

People with neurodegenerative disorders often experience problems across a variety of functional domains, including movement, cognition, and psychosocial functioning. The classification of these disorders is based on the phenotypical manifestations that represent the most prominent clinical features. For example, Parkinson's disease is typically regarded as a movement disorder, whereas Alzheimer's disease and other dementias are regarded as cognitive disorders. A problem with this classification is that it seems to disregard the fact that movement and cognition are actually strongly linked – successful motor performance does not only require the direct, physical control of muscles, but also involves cognitive control processes that allow us to engage in goal-directed behavior in the face of uncertain and/or changing environments. It therefore seems difficult (if not impossible) to separate between "pure" motor or cognitive conditions. In this talk I will show results from my work indicating that individuals living with what we currently classify as movement disorders can also experience cognitive problems, and vice versa. I propose that we should consider abandoning the classical movement versus cognitive disorder dichotomy when it comes to classifying neurodegenerative diseases.

Speakers - Consolidation

Geneviève Albouy, University of Utah

Biography: After completing a PhD in Neuroscience jointly between the Universities of Lyon (France) and Liège (Belgium, 2004-2008), Dr. Genevieve Albouy conducted a postdoc at the University of Montreal (Canada, 2009-2014). In 2015, she became an Assistant Professor in the Movement Control & Neuroplasticity Research Group in the Movement Science Department of the KU Leuven (Belgium, 2015-2020). Since January 2021, she is an Associate Professor in the Department of Health and Kinesiology at the University of Utah, USA. She is the leader of the Sleep and Motor Memory Lab and she has had the pleasure, over the last 10 years, to lead the research activities of 5 postdocs, 12 PhD students and more than 30 master and 30 bachelor students. Since she started her group, she was awarded, as PI, 9 grants including university and federal research funds to develop a research program that focuses on the study of the plasticity processes associated with sleep-related motor memory consolidation in healthy populations. Specifically, Dr. Albouy employs multimodal research approaches, including magnetic resonance imaging (MRI), electroencephalography (EEG), non-invasive brain and sensory stimulation to examine how the neurophysiological processes supporting wake and sleep-facilitated memory consolidation can be modulated to optimize motor performance, motor learning and memory retention.

Role of the Hippocampus in Wake- and Sleep-Related Motor Memory

Consolidation

Memory in humans has historically been divided into anatomically and functionally distinct systems. However, there is increasing evidence that these memory systems recruit overlapping brain areas. For example, previous research from our group indicates that the hippocampus - a brain structure traditionally associated to declarative memory - plays a critical role in procedural (motor) memory. However, the functional significance of these hippocampal responses remains poorly understood. The goal of this presentation is therefore to shed light on the role of the hippocampus in procedural motor learning and memory consolidation over short (i.e., rest periods lasting several seconds between bouts of practice) and long timescales (i.e., hours between training sessions). I will first present multivariate pattern analyses of fMRI data showing that the hippocampus binds movements to their temporal position during motor sequence learning (MSL). I will then outline how hippocampal multivoxel fMRI patterns related to MSL persist over short and longer timescales during awake rest and how these patterns can be modulated by experimental interventions. This presentation should therefore provide new insights into the role of the hippocampus in motor memory, a topic that has received limited attention in the learning and memory field.

Arnaud Boutin, Université Paris-Saclay

Sleep rhythms underlying motor memory consolidation

Sleep benefits the consolidation of motor skills, primarily through brief bursts of thalamo-cortical spindle activity (0.2-3 sec, 11-16 Hz) and associated reactivations of task-related neural patterns during non-rapid eye movement (NREM) sleep. Recent evidence showed that spindles cluster in “trains”, following an infraslow rhythm (~0.02 Hz) with spindle trains recurring every ~50 seconds, while individual spindles within these trains iterate every 3 to 4 seconds (~0.2-0.3 Hz mesoscale rhythm). This temporal cluster-based organization of spindles is considered a critical sleep mechanism for the timed and repeated reactivation of memories, although the functional significance of this organization remains unclear. Additionally, cross-frequency coupling and the hierarchical nesting of NREM oscillations–particularly slow oscillations (SO; 0.5-1 Hz) and spindles–are thought to facilitate synaptic plasticity. In this talk, I will present a series of studies examining the sleep mechanisms that support motor memory consolidation. Across several experimental paradigms, we examined how daytime sensorimotor experience shapes spindle expression (clustering, rhythmicity) and SO-spindle coupling during both nocturnal sleep and daytime naps. Overall, our findings revealed that the cluster-based organization of sleep spindles is independent of daytime sensorimotor experience. However, we demonstrated that spindles occurring within trains may promote skill-specific strengthening of motor memories, whereas isolated spindles may instead create memory-instability conditions facilitating skill generalization. We further showed that precise SO-spindle phase-locking supports skill consolidation, but only for spindles embedded within trains. Together, these dissociations highlight distinct mechanistic roles for grouped and isolated spindles in memory processing.

Simon Steib, University of Heidelberg

Exercise-induced changes in sleep microstructure: A mechanism for enhanced motor memory consolidation?

A growing body of evidence, including our own work, indicates that single exercise bouts can enhance motor memory consolidation in both healthy individuals and clinical populations. Acute exercise simultaneously elicits a wide array of transient physiological responses, which are thought to create an optimized neurobiological environment for neuroplasticity. Yet, important questions remain regarding the mechanisms and conditions under which these effects on memory occur. Because sleep plays a central role in memory formation and is sensitive to exercise-induced physiological alterations, it represents a promising candidate pathway through which exercise may influence consolidation. Preliminary findings from recent pilot studies offer initial support for this possibility. This talk will present unpublished results from a recently completed pre-registered study examining how acute high-intensity evening exercise influences sleep architecture and its interaction with motor memory formation. We employed a mixed within–between subject design in healthy young males, who were randomly allocated to either a wake or sleep group. Each participant completed both an exercise and a resting condition in randomized order prior to encoding a novel motor sequence. Sleep was assessed via polysomnography. To probe potential physiological mechanisms, we measured cortisol responses to exercise and continuously monitored body temperature during sleep. The presentation will cover both pre-registered and exploratory findings, with particular emphasis on exercise-induced alterations in sleep microstructure (e.g., sleep spindles) and their relation to motor memory consolidation. An outlook on putative underlying mechanisms and forthcoming analyses will also be provided.

Pierre Vassiliadis, EPFL, CH and University College London

Real-time reinforcement of a motor skill

Movement, like perception and cognition, is fundamentally shaped by the pursuit of reward. Across species, reward is known to be a powerful modulator of action, guiding action selection, movement invigoration and reinforcing successful behavior. Most work on reward has leveraged decision-making paradigms, in which agents have to learn to select among a discrete number of actions through reinforcement. Growing evidence indicates that reward is also instrumental in tasks with richer motor demands, such as motor learning, where individuals refine movement kinematics through practice. These studies have largely delivered endpoint reinforcement after discrete movements. Yet, real-world movements are often complex, requiring to control many degrees of freedom over extended periods of time with substantial sensory uncertainty. In this talk, I will present a personalized real-time reinforcement learning approach delivering reinforcement feedback during continuous movements. Testing this approach on 88 healthy participants and 18 chronic stroke patients, we find and replicate that this strategy can improve motor control and retention, in particular when the quality of sensory feedback is low. Using information-theoretic analyses, we further show that real-time reinforcement increases the reliance on a specific feedback control mechanism, allowing exploitation of success, but only when sensory feedback is uncertain and that this mechanism is associated to gains in retention. Finally, combining transcranial temporal interference stimulation (tTIS) of the striatum and fMRI, we show that 80Hz, but not 20Hz, stimulation of the striatum abolishes reinforcement-related gains in retention, pointing to the causal role of high gamma striatal rhythms in reinforcement motor learning. Together, these results delineate the promise, limitations, and mechanisms of real-time reinforcement for motor learning and rehabilitation.

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Poster Abstracts – Neural Plasticity

P1: The emergence of new coordinative structures in de-novo motor learning

Bongers, R.M.[1] & Mehta, A.[1]
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Abstract: De-novo motor learning involves searching for novel coordinative structures that organise abundant degrees of freedom (DOF) in the movement system. Coordinative structures temporarily constrain DOF in a functional unit. Here we took joint angles as the relevant DOF. Coordinative structures can be represented with a solution manifold in the state space spanned by the involved joint angles (DOF space). Search for a novel coordinative structure involves moving through the DOF space to find the solution space, and on the solution space to incorporate task constraints. We characterised these search processes and the role different types of variability play in it. We employed a virtual lateral interception task using a body machine interface introducing a novel redundant mapping between upper limb joint angles and the virtual paddle position. Participants had to learn this mapping, reflecting the novel coordinative structure to accurately control the paddle. With practice participants learned intercepting the ball. First, the novel coordinative structure was initially not present and formed over practicing. Second, search was larger for random practice schedules than for blocked practice schedules, and independent of participants' intrinsic variability. Third, during practicing homing in onto the solution space is faster than traversing along the solution space.

P2: Touch Localization After Peripheral Nerve Repair: Longitudinal Outcomes Show Marked Individual Variability

Benjamin Govier[1], Martin Weber[1], Andrew Marshall[2], Obi Onyekwelu[3], Louise Booth[4], Edwin Jesudason[4], Vivien Lees[5], Ken Valyear[1]
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Peripheral nerve injury of the upper limb constitutes a significant healthcare challenge. Notwithstanding advanced surgical repair, where the proximal and distal ends of transected nerve(s) are reunited, outcomes remain heterogeneous. Deficits in the ability to localize touch—locognosia—are frequently observed and may reflect inaccurate regrowth of nerve fibers. The long-term trajectory of locognosia deficits is unknown. In this study, locognosia was measured in sixteen patients with transection injuries of the median/ulnar nerves. Locognosia error was calculated for targets within the territory of the repaired nerve(s), separate from misreferrals—errors made across digits. Error for homologous targets on the non-injured hand was measured for comparison. Testing occurred at two time points, with a median interval of 17 months (range: 6-23 months). Group-level results reveal no differences in locognosia error between tests for either hand. However, the injured hand shows marked variability, with four patients exhibiting changes that exceed the highest levels observed in the non-injured hand by at least two-fold. Two of these patients improve, while the other two decline. Our results highlight the heterogeneous nature of outcomes in peripheral nerve repair. As Thomas Brushart suggests, each patient case should be viewed as a unique "experiment in regeneration biology".

P3: Cortical and Subcortical Neural Representations in Action Planning

S Marchant[1], C Zandvoort[1], B Ingram[1], H Wright[1], S Wang[1], A Bagshaw[1], K Kornysheva[1]
[1]University of Birmingham

How does motor cortex, striatum and hippocampus coordinate motor sequence planning? Synchronised oscillations are fundamental to brain function and altered in neurological patients (Barone and Rossiter, 2021; Buzsaki, 2006; Buzsáki and Moser, 2013). However, the computational contribution of oscillations in key cortical and subcortical areas to skilled motor control remains debated. Recall and production of learned motor sequences involves multiple neural representations through the process: from a high-level, abstract representation of movement to low-level, effector-dependent representations of individual movements (Yewbrey et al., 2023; Yokoi and Diedrichsen, 2019). We hypothesise a hierarchically organised framework of representations in oscillatory activity. Representational Similarity Analysis has previously been used for the fusion of different neuroimaging modalities (Cichy et al., 2014; Cichy and Pantazis, 2017). In a novel application of this method, we will fuse band-pass filtered EEG with fMRI in order to localise neural representations within different frequency bands of oscillatory activity. We will then identify the contribution of oscillatory activity to levels of representation: effector-dependent representations; body-centred representations, and abstract representations of a motor sequence. This work will localise – both temporally and spatially – the cortical and subcortical oscillations during motor sequence planning.

P4: Neural state switch underlies the transition from movement preparation to execution in humans

Ziwei Yin[1], Jian K. Liu[1], Katja Kornysheva[1]
[1]University of Birmingham

Disentangling the neural mechanisms of movement preparation and execution is essential for understanding motor control in complex motor tasks. In non-human primates, invasive recordings show that the same neural populations are active during both phases but occupy distinct, orthogonal subspaces. Human fMRI studies reveal differential spatial activation, yet the temporal dynamics of these transitions remain unresolved. We used magnetoencephalography (MEG) during a delayed finger-sequence task to track high temporal resolution activity in motor cortical regions and the hippocampus. Linear discriminant analysis (LDA) decoding showed that phase transitions began shortly after the go cue and preceded movement onset, with region-specific timing: the hippocampus transitioned earliest, followed by premotor areas, with M1 shifting closest to movement onset. Low-dimensional trajectories revealed a shared state space in which preparatory and execution states occupied distinct subregions, as evidenced by significant differences along principal component axes and increased Euclidean distance between phases. Clustering analysis of covariance matrices in a continuous sliding-window fashion revealed temporally evolving regional spatial activation patterns. Sliding-window decoding of sequence identity and its correlation with oscillatory power yielded weak effects and no dominant frequency, suggesting that full-band population dynamics with phase information encode richer preparatory information than band-limited features. These results demonstrate that non-invasive MEG can resolve continuous neural state transitions underlying motor preparation and execution in humans. This approach provides mechanistic insight into motor population dynamics and supports the development of BCIs with higher temporal precision.

P5: Uncovering the flexible control of cortico-cerebellar circuitries in human sensorimotor timing

Coen S. Zandvoort[1], Charlotte Wissing[2,3], Jonathan Winter[1], Anna Kowalczyk[1], Ole Jensen[4,5], Chris Miall[1], Devika Narain[2,3,*] and Katja Kornysheva[1,*]
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Humans have the remarkable ability to accurately learn the timing of movements. Motor timing processes have long been attributed to cerebellar functioning and tested using well-established models of eyeblink conditioning. Here, one must learn temporal associations between neural conditioned and unconditioned stimuli. During persistent conditioned-unconditioned stimulus coupling, the unconditioned stimulus timing can be predicted correctly. Current theories from animal literature suggest an integrative control from cortico-cerebellar circuitries when learning distinguishable timings. However, it remains unknown how this temporal flexibility appears in macroscopic human recordings. We tested this through recording 68-channel optically pumped magnetometers magnetoencephalography in 14 participants. Participants were asked to learn associating dark and light tunnel cues with right index finger presses at 800 [720-880] and 1,600 [1,420-1,760] ms respectively. Correctly timing the motor response led to the avoidance of an air puff. We found beta-band (13-30 Hz) desynchronisation over the left supplementary and primary motor cortices (i.e., contralateral to finger press). Cerebellar sensors exhibit gamma-band (30-80 Hz) synchronisation in the 300ms after the cue, followed by beta-band desynchronisation. These initial findings reveal task-related [de]synchronisations over cortical motor and cerebellar sensors. Next, we will disentangle how these neural signatures give rise to the integrative control from cortico-cerebellar circuitries.

Poster Abstracts - Interference

P6: Reward-Accelerated Adaptation in Embodied VR: Overt Feedback Improves Visuomotor Learning

Diar Abdlkarim, Peter Holland, Joseph Galea, Chris Miall

Immersive VR (iVR) enables embodied practice with precise control of visuomotor mappings, yet the contribution of extrinsic reward to motor adaptation in such settings is unclear. We tested whether concurrent audio-visual rewards accelerate learning when the avatar hand is perturbed. Fifty-eight able-bodied adults completed a continuous target-tracking task while the avatar hand was subjected to a fixed control-to-display (CD) gain (visuomotor perturbation). Participants were assigned to a Reward group (concurrent audio-visual feedback contingent on performance) or Control (no reward). The Reward group showed earlier adaptation onset and lower tracking error across learning compared with Control, under a subtle CD gain chosen to preserve embodiment. Findings indicate that overt, concurrent rewards can enhance adaptation efficiency in realistic, avatar-based iVR without resorting to large, disruptive gains. For the motor learning community, this provides a practical recipe, embodied avatars plus lightweight reward, to boost engagement, shorten effective training time, and inform the design of scalable rehabilitation protocols and sensorimotor experiments. Immersive VR (iVR) enables embodied practice with precise control of visuomotor mappings, yet the contribution of extrinsic reward to motor adaptation in such settings is unclear. We tested whether concurrent audio-visual rewards accelerate learning when the avatar hand is perturbed. Fifty-eight able-bodied adults completed a continuous target-tracking task while the avatar hand was subjected to a fixed control-to-

display (CD) gain (visuomotor perturbation). Participants were assigned to a Reward group (concurrent audio-visual feedback contingent on performance) or Control (no reward). The Reward group showed earlier adaptation onset and lower tracking error across learning compared with Control, under a subtle CD gain chosen to preserve embodiment. Findings indicate that overt, concurrent rewards can enhance adaptation efficiency in realistic, avatar-based iVR without resorting to large, disruptive gains. For the motor learning community, this provides a practical recipe, embodied avatars plus lightweight reward, to boost engagement, shorten effective training time, and inform the design of scalable rehabilitation protocols and sensorimotor experiments.

P7: Holistic planning of sequential motor actions

Poppy Aves[1], Joseph Galea[1], Katja Kornysheva[1]
[1]University of Birmingham

Humans exhibit a remarkable ability to perform a diverse range of skilled actions, encompassing whole-body activities like driving, to intricate tasks such as handwriting. Such actions often consist of a series of sequential movements, refined through extensive practice for impressive speed, accuracy, and fluency. Planning plays an integral role in how effectively these actions are performed; however, the question of how the brain plans such movements remains unsolved. Two competing theories – serial planning, emphasizing that movements retain their independence and are executed in a serial fashion; and holistic planning, where movements fuse into a unified 'motor primitive' - persist. While behavioural studies support holistic planning, recent electrophysiological findings lean towards a serial mechanism. To probe the existence of holistic planning, participants underwent five-day training on a two-stage reaching task comprising obtuse and acute target angles, hypothesised to elicit holistic and serial planning respectively. Switching the second target during the initial movement revealed that in obtuse configurations, indicative of holistic planning, participants struggled to switch compared to acute ones. This difficulty in switching correlated with increased fusion of the two movements, suggesting that holistic planning may underlie the execution of certain well-practiced motor sequences.

P8: A Mobile Brain/Body Imaging (MoBI) approach to Individualised Performance in Dance Motor Sequence Learning

Russell W. Chan[1]*, Victoria Lakomski[1], Johannes V. R. Pannermayr[1], Emma Wiechmann[1,2], Jan-Willem J. R. van 't Klooster[1], and Willem B. Verwey[1]
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Fundamental research in motor sequence learning has typically relied on the use of fingers to uncover neurocognitive mechanisms. In recent years, there has been a shift towards whole-body tasks to truly understand the 'motor' aspect of sequence learning. In the current research, we successfully ported the popular Discrete Sequence Performance task to a dance version coined Dance-DSP. We aimed to unravel if participants use different strategies to perform the task due to individual limitations in working memory. We predict that if this is true, different concatenation points (items with slower response times) would arise between participants. This would be coupled with higher cortical activations for participants who learn the sequence poorly than those who learn the sequence better. We collected mobile EEG using ANT Neuro eego™sports, kinematics via Movella's MTw Awinda (inertial-based), and behavioural performance response times and accuracy. Grouped data did not show the same concatenation points for behavioural data from theory based on keypress tasks. Between participants, individuals showed differences in EEG and behavioural performance, suggesting differences in performance strategies. Neurophenotyping and providing personalised feedback from EEG data is the next progressive step for the application of this work.

P9: Universal effect of Contextual Interference Across Individual Differences in Motor Learning

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Practice is a key determinant of motor learning, and how it is organized significantly influences memory consolidation. Facilitating consolidation is essential for developing stable or enhanced motor memory, resulting in greater skill learning. One well-established method for encouraging post-practice consolidation is contextual interference (CI), an organization of the practice schedule. However, the influence of individual differences on the CI effect remains unknown. We examined whether the CI effect is universal or varies across individuals based on initial skill levels. We hypothesized that although learning rates may differ within conditions (fast versus slow performers in interleaved practice (IP) and repeated practice (RP)), the CI effect would still occur, as IP fosters more stable consolidation and results in superior skill learning regardless of baseline motor ability. We conducted a secondary analysis of data from 70 participants across our prior studies. Our results showed that grouping by initial skill level effectively separated participants into fast and slow performers in both IP and RP. Importantly, IP consistently led to stable memory consolidation, with significantly greater offline gains associated with sleep compared to RP. These findings confirm that IP supports more robust memory consolidation, supporting enhanced skill learning regardless of initial skill level.

P10: Posterior parietal cortex contributions to consolidation of motor memories during visuomotor adaptation are arm- and hemisphere-dependent: an anodal HD-tDCS study

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Previous research has shown that focal lesions to the left posterior parietal cortex (PPC) impedes visuomotor adaptation performance of both arms. We now investigate the role of PPC in visuomotor adaptation in the non-lesioned system using anodal (excitatory) high-definition transcranial direct current stimulation (HD-tDCS). Groups of healthy adults adapted targeted reaching movements to 30-degree rotated visual feedback in a 2D virtual environment with either their dominant right arm or non-dominant left arm, while receiving either left-PPC, right-PPC, or sham HD-tDCS. Stimulation was then switched off and the same task was performed with the opposite arm to examine inter-limb transfer of adaptation performance – a measure of effector-independent memory consolidation. We expected left-PPC stimulation to improve visuomotor adaptation performance regardless of which arm was used to perform the task. However, there were no effects of stimulation during initial adaptation, but two notable effects on inter-limb transfer: (1) Left-PPC stimulation enhanced transfer from the dominant to non-dominant arm, with no effect of right-PPC stimulation on transfer (lateralized organization), (2) Both left- and right-PPC stimulation impeded transfer from the non-dominant to dominant arm (symmetric organization). These findings indicate a specific arm- and hemisphere-dependent role of PPC in effector-independent consolidation of motor adaptation.

P11: Neural correlates of motor learning during concurrent striatal transcranial Temporal Interference Stimulation (tTIS) in healthy older adults

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Age-related decline in motor learning capacity has been linked to structural, functional and dopaminergic cerebral changes, particularly in the cortico-striatal circuit. Enhancing skill acquisition in healthy older adults may help counteract the decrease in brain volume and synaptic plasticity, and support autonomy and quality of life in an aging population. Given the striatum's central role in motor learning, striatal neuromodulation has recently emerged as a promising approach to support skill acquisition in both healthy and clinical populations (Wessel, Beanato *et al.* 2023; Proulx & Hummel 2024). Non-invasive striatal targeting has been possible via the novel technique of transcranial Temporal Interference Stimulation (tTIS) which enables the focal modulation of deep brain structures, overcoming the depth-focality tradeoff characterizing conventional NIBS methods. In this double-blind, cross-over, placebo-controlled proof-of-concept study, fifteen healthy older adults received striatal tTIS delivered in an intermittent theta-burst pattern, known to induce long-term potentiation (LTP)-like plasticity, thereby suitable for learning facilitation (Wessel, Beanato *et al.* 2023). Concurrent functional MRI was acquired, to investigate the neural correlates of motor learning under active tTIS versus the control stimulation. Behavioral and neuroimaging findings are presented and discussed in the context of identifying functional mechanisms underlying enhanced motor learning through deep-brain, non-invasive neuromodulation.

P12: Concurrent Striatal Temporal Interference Stimulation and EEG: Methodological Challenges and Implementation during Motor Learning

Stavriani Skarvelaki[1,2], Paul de Fontenay[1,2,] Ketevan Alania[1,2,] Andràs Puszta[1,2,] Pablo Maceira-Elvira[3], Greta Carnevali[1,2], Andrea Nuti[1,2,] Alexandra Psaltis[1], Shiu-Cheng Wang[1], Myles Capstick[4], Esra Neufeld[4,5], Niels Kuster[4,5,6], Takuya Morishita[1,2], Sylvain Harquel7, Friedhelm C. Hummel[1,2,8]
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Motor learning is a fundamental brain process that enables the acquisition and refinement of skilled movements, engaging distributed cortical and subcortical circuits. A key step toward understanding these mechanisms is to capture the neuronal interactions within cortico-subcortical networks at high temporal resolution. In this context, the striatum and its dynamic connectivity with cortical regions play a central role across different phases of motor learning.
Here, we present a novel methodological approach combining non-invasive transcranial temporal interference stimulation (tTIS) of the striatum with concurrent electroencephalography (tTIS-EEG) to investigate cortico-striatal neuronal interactions during motor skill acquisition.
tTIS applies multiple high-frequency (kilohertz) oscillating electric fields with slightly different carrier frequencies. Their temporal interference then generates a low-frequency amplitude-modulated envelope at the difference (beat) frequency that can be steered to deep brain regions such as the striatum, enabling non-invasive modulation of its neural activity.
The feasibility of concurrent tTIS-EEG is achieved using custom-designed hardware filters that effectively remove low-frequency stimulation artefacts. This methodological innovation allows the simultaneous recording of cortical dynamics during ongoing subcortical neuromodulation, providing a unique framework to study cortico-striatal network

mechanisms underlying motor learning in humans.

P13: Reward-based modulation of hand choice in virtual reality: Testing principles for rehabilitation design.

Ronan Timircan[1], Karl Jackson[3], Giovanni d'Avossa[1], Gavin Buckingham[2], Helen Fraser[3], Rhodri Jones[3], Panagiotis Ritsos[1], Peter Butcher[1], Ken Valyear[1]
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Upper-limb impairment can be reduced by interventions that promote use of the affected limb. Here, we test whether reinforcement learning can modulate hand choice in a virtual reality (VR) task, as a proof of concept for future rehabilitation applications. Healthy participants play a VR game involving reaching to visual targets appearing on either side of the midline. Hand choice is measured as the point in space where both hands are used equally often—the Point of Subjective Equality (PSE). In Study 1, we show that established principles from movement science reliably extend to VR. The PSE is consistently identified near the midline, where inter-limb biomechanical and energetic costs are similar, and more time is taken to initiate movements near the PSE. Both hand choice and decision times reflect predicted costs. In Study 2, we show that changing the game's point structure systematically influences hand choice. When points favour one hand, participants adjust their hand choice to increase rewards. These effects occur even when participants are unaware of the reward-structure manipulation. Our findings support the translation of movement-science concepts to VR and show that point-based manipulations can influence hand choice, highlighting the potential to harness these methods for upper-limb rehabilitation.

P14: Effects of Anodal tDCS on the StartReact Response in Young and Older Adults

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Transcranial direct current stimulation (tDCS) may counteract age-related neuromuscular decline by modulating descending motor pathways, particularly the reticulospinal tract (RST). RST excitability can be indirectly assessed using the StartReact paradigm, where a startling acoustic stimulus shortens reaction time (RT) and enhances force output and rate of force development (RFD). As RFD deteriorates with age, reduced StartReact responses may contribute to age-related motor impairments. Forty-four healthy adults were divided into Young (18–40yrs; n=24) and Old (65–80yrs; n=20) groups. Participants completed two StartReact sessions (Pre, Post) involving isometric knee extensions in response to visual (VC), visual-auditory (VAC; 80dB), or visual-startling (VSC; 110dB) cues. During the second session, either anodal (aTDCS) or sham (sTDCS) cerebellar stimulation was applied. The VSC condition significantly shortened RT and increased peak force and RFDmax versus VC and VAC (all p StartReact responses were attenuated with age, indicating reduced RST excitability. Cerebellar aTDCS enhanced rapid force production in older adults, suggesting potential for improving age-related motor performance.

P15: Classifying dance skill in step timing.

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Tapping with a periodic beat has been modeled in terms of adjusting the interval to the next tap according to the asynchrony between the previous tap and beat. We examine the applicability of this linear phase correction (LPC) model to the performance of dancers and non-dancers who, while stepping on the spot, experienced a 24% or 50% phase advance or delay in a 500 ms pacing beat on an unpredicted step. In separate blocks participants attempted to correct for the phase shift (C) or ignore it and maintain old phase (M). We describe manual and machine learning approaches to classify single-trial compensation functions (CFs; the adjustment of asynchrony after phase shift relative to value pre-shift). Manual classification shows that, in C-trials, the most common CF is consistent with LPC. This is more often the case for dancers than non-dancers. The next most common CF is delayed correction, restoring phase according to LPC, but with implementation delayed to the next step by the foot that was initially placed in error. In M-trials, maintenance of old phase and period shift are the most common forms of CF. Machine classification and clustering techniques revealed a broadly similar picture to manual classification but lacked some of the fine detail of manual classification pointing to limitations of the LPC model.

Poster Abstracts - Disorders

P16: Assessing the Impact of Home-Based Immersive Virtual Reality Intervention to Improve Motor Performance in Children and Adolescents with Developmental Coordination Disorder

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Objective: To investigate the effects of immersive VR gameplay compared to tablet-based gameplay within a home-based setting on motor performance, enjoyment, and motivation in children and adolescents with developmental coordination disorder (DCD). Methods: This crossover study included 27 children with DCD (21 boys and 6 girls) who completed two five-day, home-based interventions: (1) immersive VR gameplay (Beat Saber) and (2) tablet gameplay (Cut the Rope), playing for at least 30 minutes daily. A minimum two-week washout period separated conditions. Motor performance was assessed pre- and post-intervention using the Movement Assessment Battery for Children – Third Edition (MABC-3) and the Box and Block Test (BBT). Enjoyment using the Physical Activity Enjoyment Scale (PACES), motivation, and feelings were also measured. Results: While MABC-3 condition × time interactions were non-significant, planned contrasts showed significant pre-post improvement only in the VR condition. A significant interaction was found for the BBT, with VR gameplay yielding greater degree pre-post improvement than the tablet-based gameplay. VR gameplay also led to significantly higher enjoyment, motivation, and feeling ratings compared to the tablet gameplay. Conclusions: Immersive VR gameplay may be an enjoyable and engaging way for children and adolescents with DCD to improve their motor performance in a home setting.

P17: Parallel Planning of Motor Sequences: A Trainable Resource with Potential for Cross-Domain Transfer?

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Many everyday actions rely on planning multiple events in the correct order. Using MEG, Kornysheva et al. (2019) identified an order-sensitive activation gradient, source-localised to the parahippocampal region, during preparation of well-trained motor sequences of key presses, consistent with the competitive-queuing (CQ) model of preactivations graded by serial position. Here, we show a CQ gradient in a passive listening condition of learned tone sequences (Karagiorgis, in preparation), suggesting that CQ may underlie serial-order coding across domains. Building on these results, we will test whether training parallel planning in the motor domain transfers to non-motor sequences. Young adults will complete a six-day training protocol (Ariani et al. 2021) that expands the planning horizon of upcoming movements. We hypothesize an improved performance and a more pronounced CQ gradient in a visual serial order memory and a motor task post-training. Next, we will test older adults with pre-clinical tau pathology in the parahippocampal region to assess its effect on serial-order processing. We predict that high-tau subjects show reduced CQ gradients and memory span in the visual task, while the CQ gradient in the motor domain is preserved. Preserved motor planning could provide a reserve mechanism that is accessible via training and transfer.

P18: Caffeine, Brain-Muscle Communication, and Healthy Ageing: Insights from Non-Invasive Brain Stimulation

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As we age, declines in force production and fatigue resistance contribute to reduced independence and quality of life. A key factor is reduced corticospinal tract (CST) integrity, which impairs voluntary movement. Enhancing CST function through accessible interventions may help preserve motor function across the lifespan. Caffeine, a widely consumed psychoactive substance, influences central and peripheral neuromuscular mechanisms via adenosine receptor antagonism, but its effects on the ageing CST remain unclear. 20 younger and 20 older adults completed two double-blind, placebo-controlled sessions (caffeine: 3 mg/kg; placebo). TMS and EMG were used to derive stimulus-response curves at baseline, post-ingestion, and post-fatigue to quantify corticospinal excitability (CSE). Functional outcomes included elbow flexion and handgrip maximal voluntary contractions, and time to fatigue. Conditions are blinded as 312 and 794 until analysis is complete. Condition 312 produced significant increases in CSE, particularly at lower stimulation intensities in older adults ($p=0.011$), longer time to fatigue ($p=0.001$), and greater improvements in handgrip strength compared to 794 ($p=0.009$). These findings suggest condition 312 (suspected caffeine) enhances both central and peripheral aspects of neuromuscular function in older adults. This may reflect caffeine's capacity to counteract age-related adenosine accumulation, restoring neural excitability and the efficiency of motor unit recruitment.

P19: Decoding Movement Disorder Scales: From Item Features to Shared Principles of Motor Assessment

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Movement assessment is central to neurology, providing the foundation for diagnosis, monitoring, and treatment. In movement disorders, clinicians rely on structured observation captured through rating scales. As digital tools increasingly allow precise, scalable, and real-world measurement of motor behaviour, it is important to understand how existing scales can guide and adapt to these new approaches. We reviewed a representative set of rating scales covering parkinsonism, hyperkinetic syndromes, ataxia, functional neurological disorders, and tardive syndromes. Although their scope varies widely, motor assessment accounts for most of the content, with a median contribution of 73%. Tasks such as walking, speech, and finger–nose testing are common across scales, while condition-specific tasks appear only once, meaning that omitting them can reduce sensitivity. Viewed together, this cross-scale mapping reveals structural limitations in how current instruments capture and compare motor features across disorders. Many current scales are narrowly designed around specific phenotypes or diseases, with simplified scoring that limits cross-disorder comparison and fails to capture the multidimensional nature of movement. Our analysis supports the need for harmonised, flexible assessment protocols that sample broadly across movement disorders while integrating emerging digital technologies. We propose a concise set of core motor tasks that enable efficient, cross-disorder assessment and outline future, data-rich approaches that bridge clinical observation with technology-based measurement.

P20: Aging effects on contact dynamics in roughness perception

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The hands carry out a range of tasks from purely sensory to predominately motor. Some aspects of touched objects can be perceived from static contact alone. However, objects are commonly and optimally explored by moving the hands (active touch). Previously, in studying young adults, we found the contact forces used when discriminating the roughness of touched surfaces was related to the accuracy of roughness judgments. To further explore the interaction between movement and sensation we contrast active roughness perception in young adults with that in older (60+) adults where dexterity and passive touch perception are known to change with age. Our findings reveal that exploratory forces differ between age groups and are associated with differences in sensory acuity and skin friction. Roughness perception results support duplex theory (Katz/Hollins) highlighting the importance of movement induced vibratory signals in the perception of relatively smooth surfaces. Notably, aging effects on roughness perception are most evident during static contacts where vibratory signals were absent. The relationship between perceptual measures and contact dynamics will be elaborated in our poster.

P21: From Tacit Expertise to Quantitative Insight: A Bonsai-Based Multimodal Platform for Motor Assessment in Movement Disorders

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Clinical movement assessment has evolved through centuries of shared observation and tacit expertise, formalised in rating scales that remain costly to access and limited in scope. We present a Bonsai-based multimodal framework, extending the open-source architecture with a behavioural layer that encodes the structure of clinical examination as synchronised, analysable data streams. The framework integrates with existing and emerging motion-capture modalities, from marker-based systems to computer-vision analysis, while enabling measurement of behaviours beyond whole-body movement. This modular extension reflects the multimodal practice of neurological examination through coordinated tablet-and-pen, keyboard, webcam, and microphone nodes. Typing probes sequential finger timing and correction; digitised handwriting and drawing quantify amplitude, speed, and rhythm; webcam video extracts 3D facial kinematics for facial and bulbar control; and microphone input captures speech for prosody, articulation, and phonatory stability. By translating the depth of clinical observation into quantitative features, this new behavioural framework connects experiential assessment with computational analysis. It provides an extensible, standardised route to measure disorder-relevant behaviour, complementing motion capture while advancing scalable, technology-integrated movement assessment.

P22: β-Bursts Mark Disrupted Motor Inhibition in Medicated Parkinson’s

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Dopamine agonists in Parkinson’s disease pose a significant risk of impulse control disorders, yet the underlying neural mechanisms remain unclear. Transient β-bursts are increasingly recognised as sensitive markers of inhibitory control, beyond trial-averaged β-power. Applying linear mixed-effects modelling and threshold-free cluster enhancement, we are the first to examine β-bursting patterns relative to proactive and reactive motor inhibition in people with Parkinson’s disease (PwPD). Twenty PwPD on ropinirole and twenty healthy older adults completed an anticipatory response inhibition task while electroencephalography and electromyography were recorded to capture β- and muscle bursting dynamics, respectively. Alongside impaired response inhibition, PwPD exhibited reduced parieto-occipital and frontal β-bursting and recurrent muscle bursting, indicative of impaired top-down inhibitory signalling leading to fragmented motor suppression and delayed stopping. During response withholding, early reductions in right frontal and sensorimotor β-bursting were consistent with weakened preparatory suppression, while later sensorimotor and parietal β-bursting appeared compensatory and correlated with fewer everyday impulsive behaviours. These findings highlight the sensitivity of β- and muscle bursting to inhibitory dysfunction and related compensatory mechanisms in PwPD. Future investigation into the prognostic value of these objective markers for identifying individuals at risk of problematic impulsive behaviours will clarify their potential clinical utility.

P23: Altered neural excitation and inhibition in motor areas during skilled sequence production in individuals with Developmental coordination disorder (DCD)

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Behavioural research suggests that motor deficits in Developmental coordination disorder (DCD) are related to altered movement sequence planning, but it is unclear which neural mechanisms of motor sequence control are affected. Neural oscillations during movement planning and execution involve alpha/μ and β related movement desynchronisation (marker of motor excitation), followed by post-movement β rebound (PMBR) (marker of motor inhibition). This study examined whether adult with DCD (N=12) show reduced excitatory and inhibitory neural modulation in the perimovement phase compared to age-matched controls (N=12). Participants performed two 4-element finger sequences from memory in a delayed sequence production task over three sessions. Following a refresher, they were scanned in the Magnetoencephalography (MEG). As expected, DCD individuals had lower sequence accuracy rate ($p=.022$) and higher movement duration ($p<.001$) in correct trials. In addition, they showed reduced relative availability of upcoming movement elements during sequence planning, suggesting reduced pre-ordering of movements during planning (RT, $p=.026$; Error, $p=.014$). Time frequency results in source space revealed that correct trials showed reduced μ-related desynchronisation -600ms to 0ms before the Go cue in contralateral M1 ($p=.011$), the dorsal premotor area (PMd) ($p=.04$) and supplementary motor area (SMA) ($p=.038$) and β related movement desynchronisation in contralateral M1 (p=.007). There was less *μ and* β related-desynchronisation 0 to 500ms after the first press in contralateral M1 (p=.002; p=.006), PMd (p<.001; p=.02), PMv (p=.012; p=.014) and preSMA (p=.016; p=.035) for *μ* and β respectively and in SMA (p=.004) for *μ*. We observed less pronounced PMBR 500ms after the last press in contralateral M1 (p=.007), PMd (p=.021) and preSMA (p=.009). Our results suggest DCD is associated with a reduced capacity of the motor system to modulate rapidly in a fast-paced skilled movement task. This work advances our understanding of the neuro-functional basis of skilled motor control in DCD.

Poster Abstracts - Consolidation

P24: Rapid skill memory consolidation leads to contextualization of action representations and expansion of working memory capacity during learning

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Many real-world motor skills require the production of spatiotemporally precise action sequences that are learned through practice. We previously found that early learning for a new skill is predominantly expressed as large jumps in performance immediately following short rest breaks (micro-offline gains), and that these gains are predicted by the density of neural replay during the break. Thus, early skill learning is supported by rapid skill memory consolidation. Here, we present new MEG and behavioral findings that extend this previous work. First, neural representations of the same keypress action occurring multiple times within a skill sequence rapidly incorporate information about the local sequence context—an expression of binding that is correlated with skill gains. Contextualization of the representations increases more during rest breaks than during practice, is not explained by pre-planning effects and is specific to the trained sequence. Second, differences in within-trial speed dynamics between faster and slower skills indicate that consistent speed drops after performance has plateaued are driven by effective working memory capacity and not speed-related fatigue. Finally, we conclude by showing that skill sequence binding supported by hippocampal θ/γ PAC continues to progress over the performance plateau period, resulting in increased working memory capacity.

P25: The Role of Acute Cardiovascular Exercise in Sleep-Related Motor Memory Consolidation

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Acute exercise can enhance motor memory consolidation. Notably, exercise also impacts sleep, which is pivotal for memory. However, the interplay between exercise-induced sleep changes and motor memory remains poorly understood. In this pre-registered study, we investigate whether exercise-induced changes in sleep architecture affect motor memory consolidation. We tested 80 young men, randomly assigned to a WAKE or SLEEP group. Each participant completed two conditions: (i) high-intensity interval training (HIIT: 90%/25% Wmax) or (ii) rest (watching a documentary, REST) immediately after encoding a motor sequence (finger tapping task, FTT). The SLEEP group practiced the FTT in the evening and was retested after a night of sleep, while the WAKE group performed the task in the morning and were retested that evening. Sleep was recorded via polysomnography. Results show a higher offline change in the FTT in the SLEEP compared to the WAKE group ($p=.008$). While HIIT reduced REM sleep proportion ($p=.035$) and tended to increase NREM sleep ($p=.067$), it did not affect offline changes. Notably, the amount of offline changes was positively correlated with NREM sleep only in the HIIT condition ($r=.402$, $p=.035$). Analyses of sleep microstructure are pending and may provide better understanding of memory-related sleep changes.

P26: Pre-planning contributes to micro-offline gains

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Short breaks during early motor skill learning, in the order of a few seconds, can improve performance immediately after each break. This improvement is widely interpreted as evidence of rapid offline learning ("micro-offline gains", MOGs). Contrary to this view, we have recently shown that MOGs represent short-lived performance benefits, rather than learning, that are partially driven by motor pre-planning (Das et al., bioRxiv 2024). Here, we report results from a magnetoencephalography study that provides further evidence for a contribution of pre-planning to MOGs. 27 healthy individuals trained to produce repeating sequences of finger movements as often as possible during practice periods of 10 seconds each, interleaved with 10-second rest periods. We observed significant MOGs, i.e., faster sequence execution at the beginning of a new practice period, compared to the end of the preceding practice period. This performance improvement was predicted by the degree to which upcoming finger movements were represented in parallel during the last 500 ms before initiation of the first movement in a practice period. This parallel representation, leading up to movement execution, is a typical signature of sequence planning. Our data cast further doubt on the usefulness of MOGs as a behavioral marker of micro-consolidation.

P27: Somatosensory targeted memory reactivation for motor memory consolidation: Past, Presence and Future

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Neuronal replay of new motor memory traces is fundamental for motor memory consolidation. Such replay occurs spontaneously but can also be experimentally augmented via targeted memory reactivation (TMR), which exploits the sensory content of motor skills to trigger neuronal replay. Following evidence for the effectiveness of auditory and olfactory TMR, I previously revealed that also somatosensory TMR enhances motor memory consolidation in younger adults via hippocampal-mediated plasticity (Veldman et al., 2023). To examine the effectiveness of TMR in the context of aging, here I present data in younger ($n = 12$, 22.5 ± 1.09 years) and older ($n=12$, 71.7 ± 4.26 years) that were trained on two finger-tapping motor sequences, one of which was subsequently reactivated with somatosensory TMR via electrical stimulation of the fingertips. In a next-day retest, both sequences were tested. The results revealed that, across age groups, somatosensory TMR facilitated consolidation ($F_{1,22} = 10.111$, $p = 0.004$, $\eta_p^2 = 0.315$). Inspection of the macro-offline gains (i.e., overnight improvements) of younger and older revealed that while the offline gains were specific for the reactivated sequence in younger adults ($p < 0.001$ vs. $p = 0.927$ for reactivated and control sequences, respectively), both sequences increased in the older adults ($p = 0.024$ and $p = 0.041$). Correspondingly, the TMR-related consolidation benefit (TMR-index) was significant in young adults only ($p = 0.008$). The present data therefore suggest that TMR-specific benefits decrease with advancing age. Such effects may, however, differ in ecological tasks investigated in ongoing/future experiments.

P28: Motor Memory in Older Adults: Does Post-Encoding Cardiovascular Exercise Enhance the Consolidation of a Balance Task?

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Age-related changes in neuroplasticity may contribute to reduced motor memory consolidation. Current findings suggest that cardiovascular exercise (CVE) foster neuroplastic processes. Accordingly, a single bout of CVE after skill practice has been shown to enhance motor consolidation, but evidence in older adults remains scarce. We randomly assigned 74 healthy, community-dwelling older adults (60-80 years) to either 30 minutes of CVE or seated rest, which they completed immediately after motor task practice. The task (stabilometer) required participants to balance a platform horizontally, while time in balance (within ± 5°) served as outcome measure. We assessed motor memory consolidation by calculating relative offline changes from the end of practice to a 24-hour retention test. Contrary to our expectations, CVE did not enhance offline changes (p=.261). Interestingly, exploratory correlation analysis indicated that the effects of CVE depended on participants' fitness level (p=.008), with fitter individuals in the CVE group showing greater offline changes (p=.032). We also assessed sleep using actigraphy to explore potential associations between exercise-induced sleep changes and consolidation; these analyses are ongoing. This is the first study to suggest that post-encoding CVE may promote motor memory consolidation in a fitness-dependent manner, with potentially important implications for an aging population.

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