7th International Autumn School on Movement Science

Berlin, 4th to 6th October 2023

Program

Hosted by

Humboldt-Universität zu Berlin, Institute of Sports Science

BSMS – Berlin School of Movement Science

Organization

Scientific Coordination
Prof. Adamantios Arampatzis (Spokesperson)

Administrative Coordination
Martina Piotrowski

Executive Committee
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Prof. Marc Kraft
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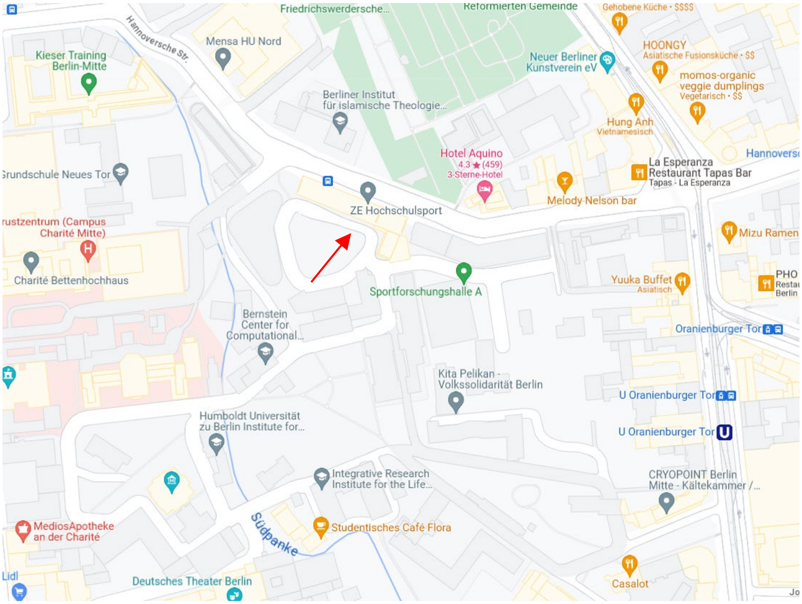
General Information

Venue

Address

Humboldt-Universität zu Berlin

Department of Training and Movement Sciences Philippstr. 13, building 11, lecture Hall 5 (Room 1.26)
10115 Berlin
52°31'36.8"N 13°23'00.7"E



The Wi-Fi network eduroam (education roaming) is available at the venue. Students, researchers and staff can obtain Internet connectivity across the campus using the respective institutional credentials.

General Information

The Autumn School and the BSMS

The Berlin School of Movement Science (BSMS) is an interdisciplinary education program based on scientific exchange and interaction, supporting PhD students to become highly skilled scientists in the fields of motor control and movement science. Our main research objectives are:

(a) to acquire knowledge about the fundamental principles of motor control in human movement,

(b) to investigate the effects of the musculoskeletal properties on the motor control strategies used during movement and

(c) to understand how the sensory-motor system controls biomechanical features and lead to adaptation on a structural level in tissues such as bone and muscle.

The BSMS organizes yearly an International Autumn School on Movement Science for young scientists to give first-hand experience of the unique graduate training program in the field of movement science.

The participation to the Autumn School is free of charge and is of particular interest to those Master's and PhD students who are considering doing their doctoral or post-doctoral research in the field of movement science within the BSMS network.

Scientific Program

Wednesday, 4th October
Day 1

09:30 to 10:30 **Kevin De Pauw** – Vrije Universiteit Brussel
11:00 to 12:00 **André Seyfarth** – Technische Universität Darmstadt
13:30 to 14:30 **Thomas Roberts** – Brown University Providence RI
15:00 to 16:00 **Jaap van Dieën** – Vrije Universiteit Amsterdam

Thursday, 5th October
Day 2

09:30 to 10:30 **Benedicte Vanwanseele** – Katholieke Universiteit Leuven
11:00 to 12:00 **Daniel Hahn** – Ruhr-Universität Bochum
13:30 to 14:30 **Chavaunne Thorpe** – Royal Veterinary College London
15:00 to 16:00 **Jess Gerrit Snedeker** – ETH University Zurich

Friday, 6th October
Day 3

09:30 to 10:30 **François Hug** – Université Côte d'Azur Nice
11:00 to 12:00 **Thorsten Stein** – Institute of Technology Karlsruhe
13:30 to 14:30 **Natalie Mrachacz-Kersting** – Albert-Ludwigs-Universität Freiburg
15:00 to 16:00 **Klaus Gramann** – Technische Universität, Berlin

Social Program

Wednesday, 4th October

Day 1

16:30 to 19:30 **Lab Tour and Get Together**

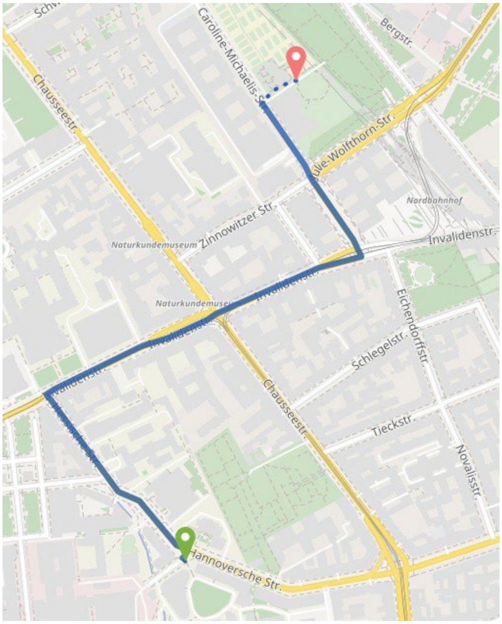
Institut für Sportwissenschaft, 10115 Berlin Philippstraße 13, building 11, room 0.26

Thursday, 5th October

Day 2

18:00 to 20:00 **Food and drinks**

BeachMitte, Caroline Michaelis Str. 8, 10115 Berlin (15min walk from venue)



Wednesday, 4th October
Scientific Program

09:30 to 10:30	Advancing quality of life through wearable robotics and prosthetics **Kevin De Pauw** – Vrije Universiteit, Brussel, BE
10:30 to 11:00	Coffee break
11:00 to 12:00	Assistance and Self-Assistance in Human Movement **André Seyfarth** – Technische Universität, Darmstadt, GER
12:00 to 13:30	Lunch break
13:30 to 14:30	A mechanical interaction between fluid and extracellular matrix influences muscle force production **Thomas Roberts** – Brown University, Providence RI, USA
14:30 to 15:00	Coffee break
15:00 to 16:00	Mediolateral stabilization of human bipedal gait **Jaap van Dieën** – Vrije Universiteit, Amsterdam, NL

Wednesday, 4th October

Abstracts

Advancing quality of life through wearable robotics and prosthetics

Kevin De Pauw – Vrije Universiteit, Brussel, BE

At the Brussels Human Robotics Research Center robotics applications are being developed with the aim to enhance the well-being of individuals, both healthy and patients. A primary focus of research lies in the development of occupational exoskeletons, designed to provide assistance to workers on the shop floor. This research line addresses the persistently high occurrence of work-related musculoskeletal disorders, particularly affecting the back (prevalence of 60%) and the shoulder/neck (prevalence of 54%).

Numerous publications have highlighted the tangible benefits of exoskeletons in improving physical performance. However, there is a notable scarcity of data concerning the cognitive load associated with wearing exoskeletons. Moreover, De Bock et al (2021) underscores the need for caution when extrapolating laboratory findings to real-world settings. In fact, it has also been demonstrated that the utilization of a shoulder exoskeleton can disrupt balance during specific tasks like drilling. Given these findings, it is clear that further comprehensive research is imperative before the widespread implementation of occupational exoskeletons within companies. Such research should encompass long-term effects and necessitates the undertaking of larger trials, as well as the acquisition of use-case specific knowledge.

In a parallel research avenue, significant attention is directed towards advancements in lower extremity prosthetic technology. Numerous papers have evaluated human responses to novel prosthetic technologies, predominantly focusing on passive devices (e.g. De Pauw et al, 2018). Lathouwers et al (2023) examined coordination patterns exhibited when utilizing an innovative advanced passive prosthesis and uncovered notable disparities in lower extremity coordination. Moving forward, it is vital for research to encompass unperturbed locomotion, enabling the transfer of research outcomes into daily activities. Notably, the evaluation of long-term effects is essential in assessing the therapeutic advantages offered by advanced prosthetic technologies in terms of improving overall quality of life.

References

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Assistance and Self-Assistance in Human Movement

André Seyfarth – Technische Universität, Darmstadt, GER

The center of gravity dynamics of human movements often follows simple movement patterns such as an inverted pendulum, elastic spring- like behaviour or combinations of both (e.g. bipedal SLIP model, elastic pendulum, Geyer et al., 2006). The body dynamics are composed of the dynamics of the body's subsystems (e.g. stance and swing legs as well as the upper body, Sharbafi and Seyfarth, 2017). In this presentation I will address the question of how the forces (or the contributions of the partial masses and accelerations) of the body part systems can generate the overall body dynamics and ask about the contribution of the muscular and neuronal mechanisms to the coordination of the partial forces to generate the body center of gravity dynamics. Based on an analysis of human gait, I will show that the subsystems work can cooperatively (Seyfarth et al., 2022), i.e. support each other like an assistance system and create advantages for the overall dynamics of human movement in different ways.

References

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Seyfarth, A., Zhao, G., & Jörntell, H. (2022). Whole Body Coordination for Self- Assistance I n Locomotion. Frontiers in Neurorobotics, 16. doi: 10.3389/ fnbot.2022.883641

A mechanical interaction between fluid and extracellular matrix influences muscle force production

Thomas Roberts – Brown University, Providence RI, USA

Skeletal muscles generate force through the interaction of actin and myosin, and the characteristics of these motor proteins influence muscle speed and power. The mechanical output that a whole muscle generates also depends on tissue and organ-level features, such as fiber architecture and the passive elastic behavior of structures associated with muscle. Work in our group is now focused on another structural element that may influence muscle force and speed: water. The high bulk modulus of water means that muscles remain essentially isovolumetric over short time scales, and it also provides a route for force transmission. Experiments that manipulate intramuscular fluid volume in isolated muscles suggest that resistance of fluid to compression is essential to loading the collagenous extracellular matrix that develops passive muscle force. Increasing muscle volume increases passive muscle force, a behavior that can be reproduced by a simple model of muscle as a fluid-filled, fiber-wound cylinder. Manipulating intramuscular fluid pressure during active contraction also affects force output but in non-intuitive ways. Squeezing a muscle at short lengths decreases force, while squeezing it at long lengths increases active force output. This behavior can also be replicated in a simple model, suggesting that an interaction of fluid pressure and the collagenous matrix surrounding fibers and fascicles is an important part of active force production. Our manipulation of fluid volume in the lab is artificial, but muscle fluid volume also changes in vivo, for example under conditions of exercise or edema. Such changes may influence muscle performance in ways that we do not yet understand.

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Mediolateral stabilization of human bipedal gait

Jaap van Dieën – Vrije Universiteit, Amsterdam, NL

Walking on two legs is challenging due to the high position of the body's center of mass (CoM), the small base of support and the CoM's movement towards the mediolateral edge of the base of support on every step. In older adults and in populations with orthopedic or neurological diseases, this often leads to injurious falls. Model studies suggest that phase-dependent feedback control of the CoM state is required to maintain a stable bipedal gait pattern. Such a feedback process would couple control actions, reflected in the ground reaction force, to the CoM state earlier in the gait cycle. Fitting of a relatively simple feedback model to gait data indeed supports that a negative feedback coupling of the mediolateral ground reaction force to the CoM state in the preceding step is present in perturbed and unperturbed walking. Mediolateral ground reaction forces can be modulated by changing the position of the center of pressure of the ground reaction force relative to the CoM (Hof, 2007). This in turn can be modulated by foot placement and by ankle inversion/eversion moments. Foot placement appears to be the dominant mechanism in unperturbed gait, but additional control is exerted through ankle moments in a way that corrects for "errors" in foot placement (van Leeuwen et al., 2021). As an additional mechanism, changes in angular momentum of body segments around the CoM can be used to generate mediolateral forces to stabilize gait. Data suggest that the latter mechanism is used only when gait is strongly challenged and the other mechanisms do not suffice to prevent balance loss (van den Boogaart et al., 2022).

References

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van den Boogaart, M., Bruijn, S. M., Spildooren, J., van Dieën, J. H., Meyns, P. (2022). The effect of constraining mediolateral ankle moments and foot placement on the use of the counter-rotation mechanism during walking. J Biomech 136, 111073.

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Thursday, 5th October

Scientific Program

09:30 to 10:30	The dynamic interplay of triceps surae muscles and tendons in optimizing human locomotion **Benedicte Vanwanseele** – Katholieke Universiteit, Leuven, BE
10:30 to 11:00	Coffee break
11:00 to 12:00	The history dependence of muscle action – highly relevant but still often neglected **Daniel Hahn** – Ruhr-Universität, Bochum, GER
12:00 to 13:30	Lunch break
13:30 to 14:30	The diverse roles of the interfascicular matrix in tendon health, ageing and disease **Chavaunne Thorpe** – Royal Veterinary College, London, UK
14:30 to 15:00	Coffee break
15:00 to 16:00	Multiscale Biomechanics and the Cell-Matrix Interactions behind Tendon Adaptation to Exercise **Jess Gerrit Snedeker** – ETH University, Zurich, CH

Thursday, 5th October

Abstracts

The dynamic interplay of triceps surae muscles and tendons in optimizing human locomotion

Benedicte Vanwanseele – Katholieke Universiteit, Leuven, BE

The triceps surae muscle group, comprised primarily of the gastrocnemii (medialis and lateralis) and soleus muscles along with their associated tendons, plays an indispensable role in human locomotion. This muscle group is pivotal for various fundamental activities such as walking, running, jumping, and maintaining postural stability. The coordinated function of these muscles and their tendons optimizes energy transfer, enhancing the overall efficiency of human locomotion by exploiting their biomechanical advantage and adapting to diverse movement demands. Consequently, understanding the dynamics of triceps surae muscle-tendon interaction not only deepens our insight into the mechanics of locomotion but also holds implications for refining rehabilitation strategies, designing biomechanical interventions, and advancing the field of human movement science. Using a combination of experimental and simulation approaches, our research group has explored the muscle-tendon interaction during walking (Delabastita et al., 2019a, 2019b), running (Swinnen et al., 2018, 2019) and jumping (Aeles et al., 2018). Throughout these studies we observed how the Achilles tendon primarily influences the muscle fascicle length and length changes during locomotion, contributing to efficient muscle force generation.

References

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Swinnen, W., Hoogkamer, W., De Groote, F., & Vanwanseele, B. (2019). Habitual foot strike pattern does not affect simulated triceps surae muscle metabolic energy consumption during running. Journal of Experimental Biology, 22(23). https://doi.org/10.1242/jeb.212449

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The history dependence of muscle action – highly relevant but still often neglected

Daniel Hahn – Ruhr-Universität, Bochum, GER

Everyday tasks like walking are powered by muscular force production, yet our ability to predict in vivo muscle forces under dynamic conditions is poor. This might be because the conventional muscle models used to predict muscle force are based on the muscle's force-length and force-velocity relations but typically neglect the muscle's contractile history, which affects the muscle's force- producing capacity and the underlying neural control. Specifically, during and following active muscle lengthening and active muscle shortening, force output is enhanced and depressed, respectively, compared with what is expected based on the generally-accepted muscle contraction theories. While this force enhancement during and following active muscle lengthening are termed transient and residual force enhancement (tFE and rFE), respectively, the force depression during and following active muscle shortening are termed dynamic and residual force depression (dFD and rFD), respectively. Accordingly, it is crucial that we better understand the history-dependent features of in vivo muscle force production to improve muscle model outputs and better estimate joint and tissue loading during human movement simulations in the fields of sports, medicine, ergonomics, and mechatronics. It is also crucial that we improve our understanding of neuromuscular function during dynamic conditions such as walking and running to improve the treatment and rehabilitation of individuals with injury and/or neurodegenerative disease, and to inform the control of wearable devices. In this presentation, you will be introduced to the history-dependent features of in vivo human muscles and the current understanding of the mechanisms underpinning the muscle's contractile history. Further, it will be shown when and how the muscle's contractile history might affects force and power production during stretch-shortening cycle contractions and during locomotion such as walking or running.

References

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The diverse roles of the interfascicular matrix in tendon health, ageing and disease

Chavaunne Thorpe – Royal Veterinary College, London, UK

Tendons are composed of highly aligned, type I collagen molecules, grouped together to form subunits of increasing diameter. The largest of these subunits, the fascicles, are bound together by a looser, less organised matrix, known as the interfascicular matrix (IFM, also known as the endotenon). Historically, the majority of tendon research has focussed on the collagenous matrix, which provides tendons with their high strength required to transfer muscle generated force to the bony skeleton. However, our work has demonstrated that specialisation of the IFM in energy storing tendons allows interfascicular sliding and recoil, providing the greater extensibility and fatigue resistance required by these tendon types (Thorpe et al., 2015). To achieve this function, the IFM has a specialised composition, rich in proteoglycans and elastin, and is turned over more rapidly than the fascicular matrix, likely to repair any microdamage to this dynamically loaded region (Choi et al., 2020). The IFM also houses a heterogenous population of cells, including IFM-specific tenocytes, mural cells, endothelial cells and immune cells (Zamboulis et al., 2023).

The IFM is disproportionately affected by ageing, with alterations in mechanical properties, matrix composition and turnover, and cell populations all occurring with increasing age, while the properties of the fascicular matrix remain relatively unchanged (Thorpe et al., 2015, Zamboulis et al., 2023). These changes may relate to the increased risk of injury seen in aged tendons. Indeed, structural changes are present within the IFM of injured tendons, which may precede damage to the fascicles. In addition, IFM-localised CD146+ cells respond to injury by migrating to sites of damage within tendon, although their role in tendon healing is yet to be defined.

Taken together, this work highlights the importance of the IFM in tendon function, and how it is altered with ageing and disease, which may open up new avenues for therapeutics.

References

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Thorpe, C. T., Godinho, M. S., Riley, G. P., Birch, H. L., Clegg, P. D. & Screen, H. R. (2015). The interfascicular matrix enables fascicle sliding and recovery in tendon, and behaves more elastically in energy storing tendons. Journal of the Mechanical Behavior of Biomedical Materials, 52, 85-94.

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Multiscale Biomechanics and the Cell-Matrix Interactions behind Tendon Adaptation to Exercise

Jess Gerrit Snedeker – ETH University, Zurich, CH

The field of tendon biology, long understudied, is rapidly gaining ground. On one hand, the tendon field is profiting from ever increasing mechanistic clarity within the broader disciplines of immunology, biophysics, matrix biology and mechanobiology. On the other hand, powerful technologies in molecular biology, biotechnology, bioimaging and data science are opening unprecedented experimental possibilities for labs everywhere. Our research group employs multi-scale imaging to identify novel mechanisms of cellular mechano- transduction (mechanical stimuli that regulate biological processes and their cellular sensors) [1,2]. Our scientific efforts aim to unwind multi-scale and multi- tissue complexity that lies both upstream and downstream of these sensors [3]. This lecture aims to introduce important insights we have derived from cell and tissue engineering approaches that we have devised to disentangle cell-system cross-talk in tissue homeostasis, damage repair, and adaptation to exercise. More broadly, we will map the tendon as a complex physiological system with tightly coordinated interplay between a mechanically regulated core and an “extrinsic tendon compartment” that consists of synovium-like tissues interfacing the immune, vascular, and nervous systems. This conceptual framework interconnects diverse aspects of tendon physiology and pathophysiology and provides a unifying picture that may help in understanding human how mechanics regulate tendon biology, including functional adaptation to exercise.

References

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Friday, 6th October

Scientific Programme

09:30 to 10:30	Insights into Neural Control of Movement from Decoding - the Activity of Large Populations of Spinal Motor Neurons **François Hug** – Université Côte d'Azur, Nice, FR
10:30 to 11:00	Coffee break
11:00 to 12:00	Control and Adaptation of Human Movements **Thorsten Stein** – Institute of Technology, Karlsruhe, GER
12:00 to 13:30	Lunch break
13:30 to 14:30	Commissural Interneurons and their role in humans **Natalie Mrachacz-Kersting** – Albert-Ludwigs-Universität, Freiburg, GER
14:30 to 15:00	Coffee break
15:00 to 16:00	Cognition in Motion – Investigating Embodied Brain Dynamics in Humans **Klaus Gramann** – Technische Universität, Berlin, DE

Friday, 6h October

Abstracts

Insights into Neural Control of Movement from Decoding the Activity of Large Populations of Spinal Motor Neurons

Francois Hug – Université Côte d'Azur, Nice, FR

The spinal motor neuron is the final common pathway of the neuromuscular system. Until recently, we had a limited capacity to measure the activity of a large population of spinal motor neurons in humans. As a result, our understanding of the neural control of human movement is mainly derived from information gained at either the supraspinal or muscle scale.

Recent advances of technology have made it possible to identify concurrent activity of dozens of motor units from multiple muscles using high- density surface or intramuscular electromyography (HDEMG). This made the classical surface EMG approach to move from a peripheral measure of muscle activation towards neural recording signals that can be used to provide a deeper understanding of the neural control of movement, and to develop neural interfacing technologies.

In this lecture, we will make an overview of the most recent advances in HD-EMG technology, of the use of this approach in neurophysiology and neural interfacing, and of the open challenges of this technique. Specifically, we will present:

Recent advances and methodological considerations for decoding motor unit activity from HD-EMG signals. We will include presentation of open- source materials for HD-EMG decomposition.

Recent work providing support for a synergistic organization of movement control at the motor neuron level. Taking advantage of the recording of a large population of motor units, recent studies provided evidence of the distribution of correlated synaptic inputs across groups of spinal motor neurons and that these groups may not necessarily fully correspond to the pools innervating individual muscles.

Advances in neural interfacing, including studies that investigate the neural constraints in motor unit activation.

References

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Control and Adaptation of Human Movements

Thorstein Stein – Institute of Technology, Karlsruhe, GER

Over the course of our lives, we learn countless movements that allow us to cope with various tasks in everyday life. A profound understanding of the control of human movements helps, for example, in the development of practice protocols in sports or rehabilitation, the development of sports (e.g. running shoes) and medical (e.g. orthoses) technologies or in the context of human-robot interaction (e.g. exoskeletons).

In the first part of my presentation I will provide an overview of challenges that the sensorimotor system has to solve in the context of motor control (Rosenbaum, 2010; Franklin & Wolpert, 2011). Based on this, I will provide a brief overview of motor control models that offer explanations of how the sensorimotor system may solve the challenges previously described. Optimal feedback control (Todorov, 2004) is, in my view, a theoretical framework with the greatest potential for the integration of different ideas. Therefore, optimal feedback control and its basic ideas will be briefly presented. One of the challenges that the sensorimotor system has to solve are the constant changes in one's own body and the environment on different time scales. As a result, the sensorimotor system must constantly adapt the control of movements. In order to be able to investigate these adaptation processes under laboratory conditions, various experimental paradigms have been developed in recent decades, of which the force field paradigm is presented in more detail (Shadmehr & Mussa- Ivaldi, 1994). Here, subjects have to interact with a robot that can simulate the physical properties of objects and change them in real time (Bartenbach et al., 2013). The works by Shadmehr (2017) and Krakauer et al. (2019) provide a comprehensive overview of the research results of recent years.

In the second part of my talk, I will present two studies in which we used the force field paradigm to investigate motor adaptation. In the first study (Herzog et al., 2022) we examined if the contextual-interference effect, which is a frequently examined phenomenon in motor skill learning, is also detectable in force field adaptation, and fitted state-space models to the data to relate the findings to the “forgetting-and-reconstruction hypothesis”. Thirty-two participants were divided into two groups with either a random or a blocked practice schedule. They practiced reaching to four targets and were tested 10 min and 24 h afterward for motor retention and spatial transfer on an interpolation and an extrapolation target, and on targets which were shifted 10 cm away. The adaptation progress was participant-specifically fitted with 4-slow-1-fast state- space models. The blocked group adapted faster but did not reach a better adaptation at practice end. We found better retention (10 min), interpolation transfer (10 min), and transfer to shifted targets (10 min and 24 h) for the random group. However, no differences were found for retention or for the interpolation target after 24 h. Neither group showed transfer to the extrapolation target. The state-space model could replicate the behavioral results with some exceptions. The study shows that the contextual-interference effect is partially detectable in practice, short-term retention, and spatial transfer in force field adaptation.

In the second study (Herzog et al., 2023), we followed the idea that computational models like optimal feedback control explain why humans move the way they move but no assumption is made about how the sensorimotor system generates optimal or good enough movements. However, these movements may be efficiently generated by a modular control architecture. In this study, we operationalized modularity using the model of muscle synergies. Specifically, we have attempted to explain transfer phenomena in the context of force field adaptation using muscle synergies. For this purpose, we designed a force field adaptation experiment in which participants trained in a restricted workspace area and were then tested for transfer to untrained workspace regions. We hypothesize that the amount of spatial transfer depends on the applicability of the adjusted synergies during training to new directions. Thirty-six participants reached in the horizontal plane (i) to five targets at -90°, -45°, 0° (straight), 45°, and 90°, (ii) to only the straight target in a force field, and (iii) in a null field for washout. After a ten minutes break, they were split into three equal- sized groups - inward (-90°), straight (0°), and outward (45°) - and reached again in the force field (iv). Thirteen electrodes captured muscle activity of the upper body and the right arm. Spatial muscle synergies were extracted (NMF) from the baseline phase (i) and tested for their ability to explain (fixed synergies and adaptable activation coefficients) the muscle patterns (R^2) in the adaptation (ii), washout (iii), and relearning (iv) phases. On the behavioral level participants adapted, deadapted, and readapted to the force field. Participants readapted faster to the straight than to the inward (-90°) and outward (45°) target. Preliminary results indicate that four synergies are needed to explain reaching in the null field (i). These baseline synergies explained less variance in adaptation (ii), washout (iii), and relearning (iv). These preliminary results suggest that muscle synergies in unperturbed reaching cannot fully explain muscle patterns employed when reaching in an environment with altered dynamics.

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Commissural Interneurons and their role in humans

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In a series of comprehensive studies, we have empirically established that sensory information originating from muscle receptors plays a pivotal role in modulating the activation of muscles situated in the contralateral limb. Notably, the observed latency of these effects is too brief to suggest transmission to higher cerebral centers, thereby pointing to a direct neural connection between opposing limbs at the spinal level. Our findings strongly indicate the existence of commissural interneurons in humans, akin to those observed in animal models, which mediate these phenomena.

These short-latency crossed responses (SLCRs) are subject to significant modulation by various factors, including the characteristics of the input to the neural system, the system's state (with potential reversal of the reflex response in certain instances), and the presence of central nervous system lesions that result in an inability to exhibit normal walking symmetry. Furthermore, these responses have a noteworthy functional impact, as they influence the center of pressure (CoP) and pressure distribution beneath the contralateral foot, and they are markedly influenced by the onset of fatigue.

In the forthcoming presentation, I will delve into these recent findings and provide insights into potential directions for future experiments aimed at further deepening our comprehension of interlimb communication.

Cognition in Motion – Investigating Embodied Brain Dynamics in Humans

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The human brain has evolved to optimize the outcome of our behavior (Makeig et al., 2009). Yet, established brain imaging approaches restrict active movement of participants to avoid artifacts from distorting the signal of interest. The behavior of human participants in experiments using functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) protocols is mostly restriced to finger movements providing only a limited range of the human behavioral repertoire (Gramann et al., 2011; 2014). However, active behavior does not only allow for interaction with the environment but also provides sensory feedback that is an essential part of the cognitive system (Engel et al., 2013). Recent technological developments allow for conducting experiments beyond established laboratory-based experimental protocols. Light-weight mobile EEG and fNIRS amplifiers can be combined with additional modalities like motion capture, eye tracking and virtual reality providing unprecedented insights into behavioural and brain dynamic states during embodied interactions with our surroundings.

Allowing active behavior of participants in brain imaging protocols, however, comes with significant challenges. Different wireless data streams have to be synchronized and artifacts stemming from active behavior of has to be dissociated from brain activity (Jungnickel et al., 2019; Klug & Gramann, 2021). In addition, leaving controlled laboratory environments comes with a decrease in experimental control over stimulation protocols. Here, virtual reality provides an opportunity to allow active behaviour of participants while controlling the experimental environment (Gramann et al., 2021).

Recent experiments using synchronized EEG, motion capture and VR revealed striking differences in brain dynamics underlying active behavior as compared to stationary desktop responses. These studies provide a critical perspective on problems arising from the combination of new technologies as well as problems when comparing outcomes from mobile with established desktop-based and movement-restricted protocols. The results indicate drastic changes in human brain dynamics underlying and accompanying active movement and interaction with an environment demonstrating the need to allow for active behavior to better understand the human brain.

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