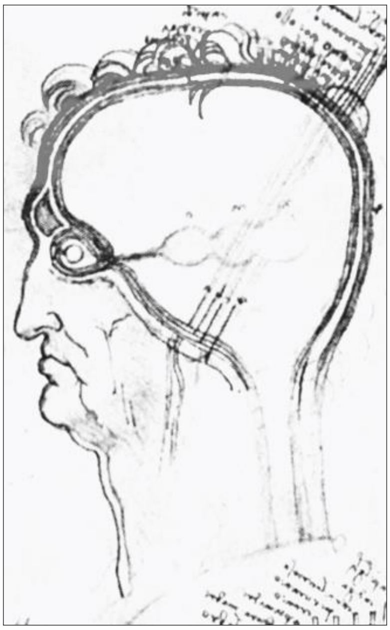
International Scientific Conference

MOTOR CONTROL 2024

From Theory To Applications

Book of abstracts



18-20 September, 2024

Wisła, Poland

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BOOK OF ABSTRACTS

Edited by Kajetan Słomka and Grzegorz Juras

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Keynote Presentations

Postural Control in Essential Tremor: Effects of Neurostimulation

Evangelos A. Christou
University of Florida, USA

Essential tremor (ET) is a prevalent movement disorder characterized by tremors in the upper limbs. More than 40% of individuals with ET exhibit unsteady gait and imbalance, predisposing them to a higher risk of falls. Deep brain stimulation (DBS) is an effective treatment in suppressing upper limb tremor in drug-refractory ET. Nevertheless, the effectiveness of DBS on gait and balance deficits remain unknown.
In this presention, I will show data how thalamic DBS implanted for upper limb tremor suppression effects tremor on various body locations and gait and balance deficits. The focus of the presentation will be on the improvements of obstacle crossing in ET patients by suppression of axial tremor via the increased synchronization of axial muscles.

In contrast to the referent control of action and perception, the classical posture-movement problem cannot be solved in the biomechanical framework

Anatol Feldman
University of Montreal, Canada

The posture 9flexes and muscle contractile apparatus (pre-flexes) are responsible for stiffness and damping resisting deflections from the chosen posture. Unlike reflexes, pre-flexes affect muscle force practically without delay. The existence of these posture-stabilizing mechanisms implies that a return of the body to the initial posture (movement reversal) would be expected in response to deflections from stabilized postures. However, movement reversals after changes in posture usually do not occur.

I will explain how the posture-movement problem is solved such that intentional changes in posture are made without reversals or resistance of posture-stabilizing mechanisms.

The mechanisms by which astrocytes mediate synaptogenesis

Michael W. Jakowec
University of Southern California in Los Angeles, USA

Background: Over the past 20 years, exercise has emerged as a means to treat the symptoms of Parkinson's disease (PD). Furthermore, evidence supports that exercise modifies disease progression. Studies from our research group have indicated that exercise, specifically skill-based forms of exercise, can target brain circuits in an anatomically specific fashion leading to changes in functional connectivity and improved behaviors, supporting its therapeutic benefits in treating PD.

Objective: One of the major goals of our research group is to elucidate the mechanisms by which exercise leads to changes in brain circuitry (synaptogenesis) impacting improvements in both motor and cognition in patients with PD and its animal models. Using rodent models of PD, we have explored these mechanisms to identify the underlying molecular mechanisms of exercise, especially those linking the brain and body, to improve the behavioral deficits in PD.

Results: Recent genetic findings have identified the role of astrocytes (glial non-neuronal cells in the brain) in mediating synaptogenesis and improving neuronal circuitry. Astrocytes appear to play a critical role in linking exercise and circuit specific synaptogenesis through the metabolite L-lactate, the glycolytic product of the breakdown of glucose. Findings will be presented showing how L-lactate, originating from either peripheral muscle during exercise, or from astrocytes themselves, acts to promote the expression of neurotrophic factors including BDNF and shuttles L-lactate to neurons, serving as a major metabolic source in energy production.

Conclusion: L-lactate, once considered a waste product of anaerobic glycolysis, is emerging as a molecule critical in promoting synaptogenesis and supporting neuronal function. Importantly, it is one mechanism by which exercise can mediate its circuit specific changes underlying functional connectivity to reverse behavior deficits in brain disorders like PD.

Intra-Muscle Synergies: Spinal Mechanisms of Action Stability

Mark Latash
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The classical concept of synergies introduced by Bernstein (1947; Latash 2020) emphasizes their two major functions: (1) Grouping of elements at the selected level of analysis; and (2) Ensuring stability of performance in the imperfectly predictable environment. Traditionally, the smallest element of synergies has been viewed as a muscle. Muscle grouping and performance-stabilizing synergies at the level of muscle groups have been demonstrated in many studies. Recently, a novel concept of intra-muscle synergy has been introduced (Madarshahian et al. 2021) and developed for different muscles (reviewed in Latash et al. 2023). This concept assumes that motor units (MU) within a muscle are grouped into a small number of modes (MU-modes) with positive covariation of firing frequencies within a mode and that MU-mode involvement stabilizes muscle force in isometric conditions. Major differences between these intra-muscle synergies and traditional multi-element synergies have been shown suggesting that the former are based on intra-spinal circuitry and the latter – on subcortical supraspinal loops. These involve the following: (1) Intra-muscle but not multi-element synergies stabilize reflex-induced changes in muscle force (Madarshahian et al. 2022); (2) Effects of hemispheric dominance are seen in multi-element but not intra-muscle synergies (Park et al. 2012; Madarshahian and Latash 2022); (3) Unintentional force drifts are accompanied by disappearance of multi-element synergies with no effects on intra-muscle synergies (De et al. 2024); (4) Fatigue leads to an increase in the index of multi-element synergies and a drop in the index of intra-muscle synergies (Singh et al. 2010; Ricotta et al. 2023); and (5) Indices of intra-muscle and multi-element synergies do not covary across healthy persons (Benamati et al. 2024). These results point at the importance of both intra-spinal and reflex-based circuits in the intra-muscle synergies. They suggest that studies of intra-muscle synergies may be of clinical importance as an index of subtle changes at the spinal level changing its contributions to stability of performance.

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Translation of motor control concepts to the understanding of motor impairment after central nervous system lesions

Mindy Levin
McGill University, Canada

The threshold control theory of motor control describes how central regulation of reflexes, including the stretch reflex, results in different motor actions, in particular, muscle relaxation, motion, and isometric torque production in single- and multi-joint systems. Control is exerted by the central nervous system (CNS) via descending systems mediating both direct and indirect influences on motoneurons. This control is manifested as the specification and regulation of Tonic Stretch Reflex Thresholds (TSRTs) in specific muscles. Injury in the CNS results in deficits in dynamic stretch reflex threshold (DSRT) and TSRT regulation leading to limitations in kinematic redundancy, the appearance of abnormal muscle activation in specific joint ranges, identified as ‘spasticity zones’, and the adoption of compensatory movements during task performance. These problems lead to decreased functional ability and decreased ability to adapt movements to task requirements. For example, people with mild stroke using excessive shoulder-elbow (e.g., arm-plane) motion can still adapt motion to compensate for deficits in reaching, while those with more severe stroke may be unable to adapt such movements to improve reaching accuracy. The relationship between disordered threshold control leading to limitations in reflex modulation and the development of motor impairments of the upper limb as well as use of the TSRT as a biomarker of disordered motor control will be presented.

The underlying Mechanisms of Exercise targeting Motor and Cognitive Function in Parkinson's disease

Giselle Petzinger
University of Southern California, USA

Background: Parkinson's disease is characterized by dopamine (DA) and synaptic loss of brain circuitry. Clinical features consist of motor and non-motor features including cognitive impairment. DA replacement offers some benefits on motor features. Currently, there are no effective treatments for cognitive deficits nor pharmacological interventions to cure or modify disease progression. In the last 2 decades exercise, specifically the field of rehabilitation, has shown promise for improving PD symptoms and impacting disease progression including providing insights towards specific rehabilitation strategies and mechanisms of repair and recovery in PD.

Objective: To review parameters of exercise involved in recovery of PD features including cognitive function. To understand the mechanisms of synaptic plasticity through exercise studies in both PD patients and animal models.

Results: Both clinical and basic research studies support that forms of exercises that engage motor skill learning lead to both motor and cognitive gains in PD. Exercise improves DA modulation as well as synaptic recovery (synaptogenesis) and these gains may be supported by exercise effects from the periphery including aspects of aerobic fitness and improved metabolism.

Conclusion: The benefits of exercise in PD arise from two principal components including (1) motor skill learning which may include aspects of cognitive engagement leading to specific repair in targeted brain circuitry as well as (2) more general effects of metabolism and fitness

Grasping and dexterous manipulation: Sensorimotor control and neural mechanisms

Marco Santello
Arizona State University, USA

Sensorimotor hand function can be described as a multidimensional space where mechanical, neural, and cognitive factors interact to enable a rich repertoire of actions. Among these actions, dexterous object manipulation plays a key role in motor development as well as activities of daily living. I will review insights gained from our research on dexterous manipulation – combining biomechanical, behavioral, neuromodulation, and robotics approaches – as a model for understanding sensorimotor control and underlying neural mechanisms. I will conclude my talk with an overview of clinical applications of our work to the design of hand prostheses and directions for future research.

How spinal reflexes (re-)define the task of the brain in movement generation

Gregor Schöner
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Even though the important role of reflex loops in voluntary movement is broadly recognized, computational models of motor control and the current methods of analysis of brain data are still often based on the (sometimes implicit) assumption that activation that descends from the brain specifies muscle activation. Clearly, spinal reflexes contribute to muscle activation. I will review results from three studies that use mathematical models of the biomechanics of an arm, of muscle force generation, and of the spinal stretch reflex to estimate from kinematic data both the time course of descending activation and the time course of the reflex contribution to muscle activation. We find that descending activation drives muscle activation only in the first 15% of movement duration. Thereafter, the reflex contribution is massive. Different patterns of descending activation are observed at different movement speeds providing evidence that the brain generates timed neural activation patterns.

Grasping is reaching with finger and thumb

Jeroen Smeets
Vrije University, Netherlands

It is tempting to describe human reach-to-grasp movements in terms of two, more or less independent visuomotor channels, one relating hand transport to the object's location and the other relating grip aperture to the object's size. We presented 25 years ago a 'new view on grasping', proposing that grasping is not about control of grip aperture, but is nothing more than simultaneous reaching with finger and thumb. I will present the experimental test of six predictions based on this proposal:
1) Digits should not be influenced by a size illusion.
2) Digits' trajectories in grasping and pushing should be similar.
3) Digits should approach objects perpendicularly.
4) Digits should respond fast to position perturbations, even if grip remains the same.
5) Movements of index finger and thumb in tapping should be adaptable in opposite directions.
6) This adaptation of digits in tapping movements should transfer to grip aperture in grasping, but not to manual size estimation.
Based on the experimental results, we conclude that although grip aperture and hand transport are convenient variables to describe grasping, treating grasping as movements of the digits in space is a more suitable basis for understanding the neural control of grasping

Body first or brain first. New prescription for Parkinson's disease

Katarzyna Śmiłowska
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Parkinson’s disease (PD) is a complex neurodegenerative disorder characterized by motor and non-motor symptoms, leading to a gradual decline in activities of daily living and overall quality of life. Various pharmacological and non-pharmacological strategies have been employed to manage these symptoms. While oral dopaminergic treatment effectively alleviates early symptoms of PD, most patients in the moderate to advanced stages of the disease experience progressively increasing disabilities despite optimal dopaminergic therapy. Motor fluctuations and complications become almost inevitable with levodopa treatment, often necessitating the initiation of device-aided therapies once the appropriate criteria are met.

However, pharmacological interventions alone are insufficient for comprehensive management. To achieve optimal outcomes, these treatments must be complemented by physiotherapy, speech and language therapy, and occupational therapy as part of the daily care regimen. Such multidisciplinary approaches are crucial for addressing the motor and non-motor challenges associated with PD. Furthermore, individuals with PD should be encouraged to take an active role in their self-management, utilizing available exercise tools and community resources to maintain their functional abilities when formal therapy is not included in the care plan. A wide range of rehabilitation, exercise, and physical activity programs are recommended for individuals with PD, emphasizing the importance of a holistic, integrated approach to treatment.

Principles of human leg design and muscle action for work avoidance and economical powering in walking and running

Jim Usherwood
The Royal Veterinary College, UK

The actions of the major human leg muscles are well established. Anatomy, inverse dynamics and computer modelling allow muscles to be described as flexors and extensors, agonists and antagonists, and as motors, brakes and struts. However, the functions of these muscle actions remain unclear; we can describe what muscles do, but not necessarily why. Here, leg muscles, bones, and their connections, are viewed as links and joints of mechanisms and structures meeting the task of a vehicle, of weight support during translation, and the two fundamental demands of an effective machine: to avoid mechanical work, and to supply mechanical work economically.

In human walking, the body rises and falls over a stance leg before a smooth step-to-step transition into the next vaulting stance. The transition results from joints effectively locking and unlocking in rapid sequence due to simple geometric changes loading and unloading a series of muscles. Remarkably, the geometry that makes the transition smoothest – and so theoretically most economical – predicts human leg and foot proportions. This may account for why modern humans have a knee half-way down their legs, short heel and toes, and a stiff, longer midfoot.

Human legs throughout a running stance are modelled as a sequence of linkages that predict muscle action and indicate the varying muscle functions within the integrated leg. Work avoidance is achieved with isometric muscles and linkages that promote a sliding of the hip over the ground contact. Work economy requires, for muscle with constrained power and a physiological cost to activation, contraction over the whole of stance; this function is achieved by the hamstrings without disrupting the linkage geometries necessary for work avoidance. In late stance, the two functions occur simultaneously through coactivation of antagonistic biarticular muscles, providing one answer to Lombard’s paradox.

The muscle actions predicted by the walking and running models broadly agree with measured EMG profiles. The principle of geometric muscle engagement – and disengagement – suggests the potential for both passive and reflexive contributions to motor control in economical gaits.

Neurorehabilitation in the 21st Century
New Science, New Strategies, New Expectations

Jonathan R. Wolpaw
National Center for Adaptive Neurotechnologies Stratton VA Medical Center & State University of New York, Albany, New York

Once considered a backwater, neurorehabilitation is now among the most vibrant areas of preclinical and clinical biomedical research. Until recently, its main strategy has been skill-specific practice, which often fails to produce adequate recovery. Now, new recognition that the CNS remains plastic through life, new understanding of the CNS substrates of skilled behaviors, and newly developed technologies combine to redefine the therapeutic goal and provide new strategies that promise to enhance the functional benefits of skill-specific practice.

The substrate of a skill is a network of neurons and synapses that may extend from cortex to spinal cord. This network has been given the name heksor, based on the ancient Greek word hexis. Each heksor changes through life; it modifies itself to maintain the key features of its skill, the attributes that make the skill satisfactory. Muscle activity and kinematics may change; key features are maintained. Heksors overlap; they share CNS neurons and synapses. Through their concurrent changes, they keep CNS neuronal and synaptic properties in a negotiated equilibrium that enables each heksor to achieve the key features of its skill.

When CNS damage disrupts important skills, the primary therapeutic goal is to enable damaged heksors to repair themselves and reestablish a negotiated equilibrium in which each can once again produce its skill satisfactorily. Two new strategies can increase the efficacy of skill-specific practice. One new strategy increases the capacity for plasticity. This gives damaged heksors more options for self-repair: they shape the additional plasticity through skill-specific practice. The other new strategy targets beneficial plasticity to a critical site in a damaged heksor. This improves skill-specific practice, which enables the heksor to achieve much wider beneficial plasticity. In animals and humans, combining skill-specific practice with these strategies produces large clinically significant improvements in recovery. These improvements persist.

For preclinical and clinical researchers, the challenge is to develop effective triple-strategy protocols – protocols that combine these new strategies with skill-specific practice. Computational modeling can help identify and parameterize promising protocols. Controlled clinical trials that evaluate a new protocol mechanistically and compare it to current state- of-the-art treatment are essential. Assessments should evaluate relevant skills, overall function, and quality of life, and should extend at least six months after therapy ends. Study of pre-morbid factors as well as reflexes, evoked potentials, muscle activity, and kinematics during treatment can guide patient-specific protocol modifications. Many triple-strategy protocols will be noninvasive and suitable for home use.

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Use of TMS to understand motor modularity and motor facilitation

Mathew Yarossi
Northeastern University, USA

Understanding corticospinal organization of muscle activation is a long-standing goal of motor neuroscience and has profound implications for interventions aimed at enhancing motor performance in health and disease. In this talk I will overview our work using transcranial magnetic stimulation (TMS) to explore motor modularity in healthy individuals. I will present evidence that modularity of hand muscle responses to TMS, measured at rest, reflects muscle modularity found during voluntary behavior involving finger fractionation. This work provides will a basis for future work using TMS to investigate muscle activation modularity in the human motor system. I will discuss our work to develop a novel experimental and computational framework for modeling multi-muscle responses to TMS of the human motor cortex using machine learning approaches. Finally, I will present our most recent work using EEG and high-density surface EMG to better understand corticospinal mechanisms of muscle activation in response to TMS.