Preface

This volume continues the tradition of the series *Progress in Motor Control* started in the previous millennium with the publication of the first volume subtitled "Bernstein's Traditions in Movement Studies" (Latash 1998). That volume contained chapters written by speakers at the first conference with the same name held in 1996 in State College, Pennsylvania. Over the past 20 years, the field of motor control has grown substantially, which is reflected in the creation of the journal "Motor Control" and the International Society for Motor Control (ISMC). The conferences *Progress in Motor Control* have become biennial meetings of ISMC, and so far seven volumes have been published forming a kind of encyclopedic compendium of motor control that is updated every other year.

Most of the chapters in this volume were written by speakers who attended the conference *Progress in Motor Control X* in Budapest, held during July 22–25, 2015. In addition, we invited several additional groups of authors who have performed new, exciting studies over the past two years. The subtitle of this volume, *Theories and Translations*, reflects the two actively developed directions of research. One of them tries to develop theoretical approaches to biological movement that would make motor control a subfield of natural science, physics of living systems. The other applies recent advances in motor control to areas such as robotics, movement disorders, brain–computer interface, and rehabilitation.

The volume consists of six parts that are focused on specific aspects of motor control. Part I, "Theoretical Motor Control", opens with a chapter by Andrea d'Avella entitled "Modularity for Motor Control and Motor Learning". The author addresses a central issue of how the central nervous system (CNS) overcomes the complexity of multi-joint and multi-muscle control and suggests that modular architecture may simplify control by embedding features of both the dynamic behavior of the musculoskeletal system and of the task into a small number of modules. Recent studies, in which human subjects used myoelectric control to move a mass in a virtual environment, have suggested that recombination of modules may be more efficient than learning or adapting a skill by acquiring new modules. According to the view of Jeroen Smeets and Eli Brenner in their chapter "Synergies in Grasping", both transport of the hand and formation of the grip emerge from a combination of independent movements of individual digits towards the surface of the object. The chapter presents three experiments designed to test to what extent movements of individual digits can be considered the building blocks of the reach-to-grasp movement. The third chapter by Katja Kornysheva, “Encoding Temporal Features of Skilled Movements—What, Whether and How?” addresses the issue of storing memories of complex temporal dynamics of movement in the brain. It outlines the constraints that determine whether and how the timing of skilled movements is represented in the central nervous system and offers a schematic model of how these different representations complement and interact with each other in fast feedback loops to achieve precise motor timing. The chapter by Dagmar Sternad and Christopher Hasson “Predictability and Robustness in the Manipulation of Dynamically Complex Objects” explores the hypothesis that humans learn strategies that make the interactions in neural representations of object dynamics predictable and robust to inaccuracies. The chapter describes a virtual reality task that simulates a cart-and-pendulum system and shows, that with practice, subjects develop movement strategies that are predictable and robust. This approach may be a promising platform to gain insights into a variety of neurological diseases and healthy aging.

Part II of the book is dedicated to the equilibrium-point (EP) hypothesis. This hypothesis was suggested in the mid-1960s by Anatol Feldman. Fifty years later, the hypothesis remains hotly debated. It has not been rejected despite multiple claims of disproving the EP hypothesis. Neither has it been accepted by most researchers. Over the past few years, more and more experimental evidence has accumulated in favor of the EP hypothesis, addressing such diverse aspects as the neurophysiological mechanisms underlying the control of movements, relations between the EP hypothesis and motor synergies, and applications of this hypothesis to movement disorders. This part opens with a chapter by Mark Latash, which presents a brief review of the EP hypothesis and its relation to the synergic control of multi-effector systems. It suggests that the EP hypothesis represents an example of a physical approach to human movements making it a subfield of the physics of living systems. The chapter describes how the EP hypothesis can be naturally combined with the idea of hierarchical control of movements and of synergic organization of the abundant systems involved in all actions. The following chapter by Anatol Feldman “The Relationship Between Postural and Movement Stability” starts with summarizing approaches to the control of posture and movement from the middle of the nineteenth century to our times. Further, the chapter describes the basics of the control with referent coordinates and their neurophysiological mechanisms. Then, the chapter addresses issues of stability of posture and movement and the role of coactivation command with an emphasis on standing and stepping. This part ends with a chapter by Mindy Levin “Principles of Motor Recovery After Neurological Injury Based on a Motor Control Theory”. The chapter describes how physiologically well-established principles in the control of actions, such as those outlined in the EP hypothesis, can help advance the understanding of deficits that may limit recovery at two levels: Body structure and function level and Activity level. In particular, the chapter addresses spasticity as a reflection of disordered control of the threshold of the tonic stretch reflex and offers practical lessons for motor rehabilitation.

Part III of the book addresses neurophysiological mechanisms of motor control. The chapter by Richard Carson and colleagues, "What Do TMS-Evoked Motor Potentials Tell Us About Motor Learning?" reviews the role of transcranial magnetic stimulation (TMS) in studies regarding the effects of motor learning. The authors emphasize the restricted explanatory scope of the TMS technique and consider a specific example of cross education: the interlimb transfer of functional capacity. Winfried Mayr and colleagues cover in their chapter, "Motor Control of Human Spinal Cord Disconnected from the Brain and Under External Movement", the role of the spinal cord in motor control and coordination. They describe a model of the human spinal cord with reduced and altered motor control and discuss how knowledge about human motor control as well as neurophysiology teach us to perform external modification of upper motor neurons by electrical stimulation and external control of afferents to spinal cord. Anticipatory adjustments during object manipulation are described in the chapter by Thomas Schneider and Joachim Hermsdörfer entitled "Anticipation in Object Manipulation: Behavioral and Neural Correlates". The authors review studies using brain functional imaging and examining the deficits of patients with localized brain damage to provide an insight into the basic principles of anticipatory motor control and their underlying neural substrates.

Part IV dedicated to problems of learning skilled behaviors opens with a chapter "Brain Plasticity and the Concept of Metaplasticity in Skilled Musicians" by Eckart Altenmüller and Shinichi Furuya, which explores the importance of brain plastic adaptations for enhanced sensory, motor, and cognitive functions. In particular, the authors focus on plastic changes in neuroplastic functions, so called metaplasticity, in musicians. The potential role of this mechanism for prevention of developing maladaptive changes in the nervous system, possibly leading to focal dystonia in musicians, is discussed. The next chapter, "The Coordination Dynamics of Observational Learning: Relative Motion Direction and Relative Phase as Informational Content Linking Action-Perception to Action-Production" by John Buchanan, emphasizes identifiable movement features that constrain and inform action-perception and action-production processes. The author puts forth relative phase as an informational variable that links perception to action. Across a series of tasks, it is shown that the relative motion and relative phase between limbs and joints are picked up through visual processes and support the observational learning of motor skills. Elizabeth Torres reviews new technological advances and new analytical methods in the study of movements and their changes in the clinical setting in a chapter titled "Rethinking the Study of Volition for Clinical Use". She emphasizes the importance of variability in the emergence of movement patterns and presents examples of solutions amenable to the habilitation and rehabilitation of volition in patient populations.

Part V of the book covers the field of impaired motor control and rehabilitation. Sainburg and colleagues in their chapter titled "Motor Lateralization Provides a Foundation for Predicting and Treating Non-paretic Arm Motor Deficits in Stroke" address clinical implications of the dynamic dominance hypothesis. This bilateral hemispheric model of motor control has successfully predicted hemisphere-specific motor control and motor learning deficits in the ipsilesional, or non-paretic, arm of patients with unilateral stroke. The chapter reviews a series of studies about the effects of intense practice of virtual reality and real-life tasks that lead to improved control of the ipsilesional arm in functional tasks. The chapter by Jozsef Laczko, Mariann Mravcsik, and Peter Katona "Control of Cycling Limb Movements: Aspects for Rehabilitation" addresses two aspects in the research on kinematics and muscle activation during cycling lower and upper limb movements. One of them deals with the effects of external load and resistance on the variance of movement patterns at different levels, from muscles to joint configurations and to limb endpoints. The comparison of the variance indices in the dominant and nondominant arms drives attention to a special feature of arm cycling that is common for both arms. The second aspect is related to functional electrical stimulation as a means to drive cycling movements in individuals with a spinal cord injury. The advantages of applying and controlling these types of movements in rehabilitation of people with paralyzed limbs are discussed. The chapter by Andrew Gordon entitled "Impaired Voluntary Movement Control and Its Rehabilitation in Cerebral Palsy" reviews the pathophysiology and mechanisms underlying impaired upper extremity control in cerebral palsy. Further, the author shows that the developing corticospinal tract can reorganize its connectivity depending on the timing and location of the CNS injury, with implications for the severity of hand impairment and rehabilitation. The chapter ends by describing evidence for motor learning-based therapies and outlining the future directions for rehabilitation. The chapter by John Rothwell addresses the effects of transcranial magnetic stimulation (TMS) on motor behavior, motor learning and on outcomes of presently applied rehabilitation therapies. It analyzes the question of whether non-invasive brain stimulation can enhance motor recovery after stroke. At the end of the chapter, new approaches are discussed that may lead to reliable and effective therapeutic treatments in medical rehabilitation.

Part VI of the book summarizes the recent progress in the field of the human–machine interface. Rajiv Ranganathan and Robert Scheidt address the learning of skilled behaviors in their chapter "Organizing and Reorganizing Coordination Patterns". They discuss how a new coordination pattern is acquired and refined when one learns a novel motor task. To examine this issue, the authors describe a body–machine interface paradigm. Then, the lessons of this paradigm for motor learning are outlined, especially for learning of motor patterns in high-dimensional spaces.

Davide Piovesan addresses the use of robot-assisted rehabilitation in the chapter titled "A Computational Index to Describe Slacking During Robot-Therapy". Robot-assisted arm movements were examined in stroke survivors; with training, the patient became able to execute voluntary movements with lower force levels and followed a minimum effort trajectory. This study offers new important insights into the rehabilitation of stroke survivors.

Tucker Tomlinsom and Lee Miller address the remarkable ability of paralyzed patients to control movement of a prosthetic limb or even their own hand with cortical signals in their chapter "Toward a Proprioceptive Neural Interface That Mimics Natural Cortical Activity". They emphasize the importance of somatosensation, including proprioception, for the natural control of movement and review studies focused on refining these sensations by stimulating the somatosensory cortex (S1) directly. Further, they describe the recent efforts to develop afferent neural interfaces through spatiotemporally precise intracortical microstimulation.

This volume is written for well-versed readers of the field. It presents a wealth of up-to-date material on various issues in the field of motor control and is designed as a reference book. It can also be used as an additional reading for graduate-level courses in such fields as physiology, psychology, kinesiology, engineering, physical therapy, and movement disorders.

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