

Preface

This volume and all the previous volumes of the Progress in Motor Control series are united by a common theme: understanding the basic principles and mechanisms underlying the control and coordination of voluntary movement and relating these findings to gain insights into the impact of pathology and injury on the sensorimotor control system. This volume contains contributions by scientists invited to participate in the meeting of the Ninth Progress in Motor Control, held in Montreal, Quebec, Canada in July 2013. Progress in Motor Control international meetings are held bi-annually and are the official scientific meetings of the International Society of Motor Control (ISMC; www.i-s-m-c.org). At the 2013 meeting, there were 28 invited presentations organized into 6 symposia, and a special pre-Congress symposium on advances in cerebral palsy research organized by Annette Majnemer and Carol L. Richards. During the meeting, the Society bestowed its highest recognition, The Bernstein Award, to Dr. Gregory Orlovsky for his outstanding contribution to the understanding of the organization of posture and locomotion.

The mission of the ISMC and the Progress in Motor Control conference series is to promote basic and applied research that furthers our knowledge of the understanding of the control of movements in biological systems. An equally important goal of the Society is to promote knowledge transfer and exchange between basic and applied scientists, educators, and clinicians. Motor control scientists come from diverse backgrounds, including bioengineering, biomechanics, biophysics, genetics, kinesiology, neuropsychology, neuroscience, rehabilitation, speech and language, and sports sciences. A relatively new addition to this multidisciplinary field, represented in the current volume, is the area of the performing arts, including dance, music, and circus arts.

The current volume is divided into four parts. Part I, “Sensorimotor Integration” includes 6 chapters. Chapter 1 presents an integrated view of motor control based on referent variables organized into a hierarchical system. The view is supported by evidence of how multiple motor elements, such as segment positions and finger forces, produce feed-forward, anticipatory synergy adjustments. Chapter 2 continues on this theme and presents the notion of referent control, which describes how movement is produced due to the difference between the referent position of the body segments set by the nervous system and the actual position of the body

segments due to its interaction with the physical environment. The concept is supported by empirical evidence of changes in corticospinal excitability during voluntary and involuntary movement. The concept is also extended to provide a new explanation of position sense that is not dependent on notions of ‘sense of effort’ or ‘efference copy’. Chapter 3 describes some of the properties of a basic element of the sensorimotor system: motoneuronal firing behavior. This in-depth chapter describes persistent inward currents and their neuromodulatory systems that are matched to the basic motor behaviors of posture, voluntary movement, and locomotion. Chapter 4 continues on the theme of locomotion with a description of the regulation of limb stiffness during locomotor tasks. Using a decerebrated cat model, the authors extend their previous studies to show how pattern generation, endpoint stiffness, and proprioceptive feedback are modulated in a task-specific way during upslope and downslope walking. The role of the vestibular system and neck proprioceptors on the modulation of these properties is discussed to explain the regulation of whole-body locomotion. The role of sub-cortical systems in the control of voluntary limb movement in humans is further elaborated in Chap. 5. Using rapid unexpected target jumps during upper limb reaching movement and lower limb stepping, the authors show that corrective movements occur at very short latencies consistent with a sub-cortical visuomotor mechanism. Finally, Chap. 6 returns to the notion of perception discussed in Chap. 2. The authors propose a multisensory binding model of the perception of the location of body segments and question the role of motor simulation in this process.

Part II of the volume deals with the concept of variability in motor control. All three chapters in this part provide evidence to support the view that kinematic variability is not simply an undesirable manifestation of the noise within the system. On the contrary, they suggest that variability is a necessary and desirable consequence of purposeful control strategies. Chapter 7 is a review of the Uncontrolled Manifold Model (UCM), by two of its original formulators. The UCM enables researchers to classify the variability of a redundant number of kinematic degrees of freedom with respect to their contribution or non-contribution to the motor goal, and provides a means by which motor equivalence and self-motion during movement can be interpreted. Chapter 8 presents a methodological approach to study complex skills that have extrinsic redundancy and dynamic characteristics. The authors provide examples of how humans find stable solutions to the redundancy problem so that movements are minimally affected by unexpected perturbations. The third chapter in this part, Chap. 9, also uses a computational approach to provide an explanation of how redundancy influences the structure and variability of repetitive movements, using goal equivalent manifolds. Based on this theoretical approach, the authors suggest that the nervous system uses a minimum intervention principle to produce movement that minimizes variables at the level of the task goal.

Part III includes three chapters on the performing arts devoted to dance (Chap. 10), music production (Chap. 11), and circus performance (Chap. 12). Chapter 10 extends the concept of action-perception via mirror neurons to action-observation learning of whole-body movements amongst professional dancers. Chapter 11 explores the highly specialized training of musicians in multi-sensory and emotional domains. Musician-specific injuries in the motor domain such as overuse injuries and dystonias,

as well as those linked to psychological mechanisms are invoked as contributing to such injuries. This new classification, which takes into account both motor and psychological mechanisms may help define prevention and treatment interventions. Chapter 12, written by a professional artist and a medical doctor specializing in prevention and treatment of performance-related injuries, reviews the specific skills needed by highly specialized circus arts performers in an entirely new domain for the field of motor control and learning, thereby providing important insights into the care of these athletes.

Part IV of this volume includes three chapters about motor control approaches to the understanding of musculoskeletal and neurological injury and recovery. Chapter 13 reviews musculoskeletal disorders of the neck and shoulder region, especially those related to occupational injuries after fatigue. The concepts of variability and motor abundance are discussed as ways for the system to restore function in chronic musculoskeletal disorders. Chapter 14 presents evidence of disorders of motoneuronal threshold control, a concept based on the equilibrium-point theory of motor control, as a primary mechanism underlying disorders of movement in patients with acquired brain injury such as stroke. Evidence supporting the role of the corticospinal tract in modulated motoneuronal thresholds is discussed. This concept may provide a link between the observations of spasticity and disordered motor control that has important implications for rehabilitation. Finally, Chap. 15 discusses the sensorimotor contributions to balance and locomotor deficits in people with multiple sclerosis. The chapter presents novel methods for quantifying stability and adaptability of posture and gait and discusses how these methods may inform the development of new treatments for people with neurological dysfunction.

The chapters in this volume present state-of-the art methodologies and insights into motor control concepts that are essential for the understanding of skilled movement and motor learning in healthy individuals and in those with musculoskeletal and neurological deficits. The chapters are written for the informed reader who has some background in movement production, measurement methods, skilled performance and/or rehabilitation. The volume will be a valuable reference for students and professionals in both basic and applied areas of motor control such as neurophysiology, biophysics, biomechanics and bioengineering, neuropsychology, kinesiology, sports science, motor disorders, rehabilitation and the performing arts.

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