Progress in Motor Control VIII

Recent Advances in Neural, Computational and Dynamical Approaches

July 21-23, 2011
University of Cincinnati
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Symposium Abstracts

&

Poster Program
Progress in Movement Disorders: Selected Topics

Mark Hallett
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Advances in movement disorders go hand-in-hand with advances in motor control, each area influencing the other. Parkinson disease (PD) has been the subject of considerable research, much focusing on the basal ganglia influence on movement. In motor learning, as movements become automatic, the basal ganglia become more strongly connected to their cortical target; a deficiency in this process in PD may explain the patients' difficulty in automating movement. The most dramatic advance in therapy of PD is deep brain stimulation (DBS), but the mode of its action is not clear. One finding that seems relevant is that there is a strong oscillation in the PD basal ganglia in the beta frequency that appears to be anti-kinetic. Successful therapy reduces this oscillation. Dystonia manifests overflow movement and studies of this have illuminated the process of selective motor control. This involves a process of surround inhibition which likely utilizes inhibitory processes at multiple levels including in the motor cortex itself. Dystonia also demonstrates abnormal plasticity. Plasticity is “increased” and appears to violate the homeostatic principle. Loss of inhibition and violation of homeostasis may lead to abnormal cortical representations that appear difficult to reverse. Psychogenic movement disorders are getting increased attention since movements look like normal voluntary movements but are said by the patients to be involuntary. Thus, there is an abnormality of both willing and agency, important normal processes. Movements in these patients may arise from abnormal influences from the limbic control of movement, and loss of agency may arise from faulty feedforward signals to the temporoparietal junction region. The relationship between the brain’s movement preparation and the conscious recognition of willing has also been explored, and this should help illuminate the differences between voluntary and involuntary movement.
Mirror Neurons in Humans? Examining the Evidence

Morton Ann Gernsbacher
University of Wisconsin-Madison

Mirror neurons are believed to be neurons that fire both when an animal spontaneously executes an action and when the animal spontaneously observes another animal executing the same action. It is also widely believed that mirror neurons have been documented in human inferior frontal gyrus, among other neural regions; that mirror neurons underlie a wide array of human phenomena, from imitation to the understanding of intentionality; and that some humans, most notably autistic humans, lack entirely or have severely defective mirror neurons. This presentation will review the empirical evidence for these claims.
The research of the last ten years was crucial for specifying in more details the properties of mirror neurons in monkeys and in demonstrating the anatomo-functional underpinning of a mirror mechanism in humans. On the monkey side, for instance, it was demonstrated the presence of mouth mirror neurons and of those responding to listening action sound. Furthermore, it has been recently shown that the response to an observed motor act can be modulated by the space sector in which the act is performed, with implications for the link between action understanding and the observer’s behavioural reactions. On the human side, evidence accumulated in favour of an involvement of the mirror matching mechanism in several types of social functions, such as imitation, speech comprehension, empathy and understanding of motor intention. All these findings suggest that a resonance behavior, possibly based on the mirror matching system, is a general principle in primates. While in monkeys this capacity seems to be strictly confined to transitive movements and some meaningful oro-facial gestures, in humans it is extended also to intransitive movements. These properties and the plasticity of the mirror system in humans can be possibly exploited, as some work already showed, for some forms of observation-based motor rehabilitation.
Movement Fragment Representations in the Motor Cortex

Nicholas Hatsopoulos
University of Chicago

Almost 100 years ago, Sherrington used electrical stimulation to argue that the motor cortex constituted a palette of small fractional yet coordinated movements which could be combined in different ways to create the rich variety of complex motor actions that are ubiquitous in everyday life. This view implies that motor cortex comprises a sort of language of motor actions where individual motor cortical neurons encode an alphabet of movement primitives instead of abstract parameters of movement. We have previously shown that motor cortical neurons encode temporally-extensive movement fragments lasting 300-400 ms in duration instead of static movement parameters during two-dimensional reaching movements. We have now extended these results to more natural three-dimensional reaching and grasping. By recording multiple single units in the primary motor cortex while monkeys reached for and grasped different objects, we demonstrate that the responses of these neurons are more accurately predicted if one assumes that individual neurons encode synergistic fragments of movement associated with the natural kinematic covariations of prehension.
Vicarious Role of Premotor Cortex After Primary Motor Cortex Lesion

Numa Dancause
University of Montreal

Following lesions in the arm and hand representation of the primary motor cortex (M1), there are behavioral deficits in the fine control of force, movement and posture of the contralateral arm and hand. However, in the weeks and months following the lesion, there is a functional recovery. This recovery is accompanied by dramatic structural and physiological reorganization within the tissue surrounding the lesion but also in other distant cortical areas. These later changes suggest that functional recovery could be dependent upon adaptive plasticity of intact, remaining brain structures, a phenomenon often referred to as “vicariation of function”. In the case of a lesion in M1, the premotor areas, with the extensive interconnections they share with other areas within the motor network, their corticospinal outputs, and the motor related activity they boast prior to the lesion, are particularly well positioned to vicariously take over the lost M1 function. I will discuss recent evolution of our knowledge of the events that parallel recovery within the premotor cortical areas of the ipsi- and contralesional hemispheres.
Bringing Feedback Back to Primary Motor Cortex

Stephen Scott
Queens University

Primary motor cortex (M1) plays a crucial role in voluntary control and has been studied for many, many years. However, there remain very divergent opinions on how it contributes to motor execution. The focus has been largely on identifying the features of movement that are represented in the discharge patterns of its neurons. Implicit in this approach has been the notion that M1 specifies feedforward descending commands, and that online feedback is provided only at the spinal level. I will argue that M1 is better viewed as forming part of a crucial feedback pathway to support voluntary control. I will present recent work from our lab that highlights how afferent feedback quickly arrives in M1 and can be modulated based on the behavioural goal. Further, I will show how feedback through M1 is also involved in specifying rapid motor responses that consider the mechanics of the limb following mechanical perturbations.
Generating goal-directed movements entails (1) preparing the movement by specifying movement parameters based on information about the scene; (2) initiating and terminating the movement; (3) generating and coordinating the time courses of control variables; and (4) controlling the physical plant. Process models of all four functional components of movement generation have been provided within the framework of dynamical systems' thinking, in many cases using ideas from neuronal dynamics. I will discuss how it all fits together, review neuronal and behavioral signatures of the postulated dynamic principles, and illustrate the feasibility of the neural dynamics account through robotic demonstrations.
Understanding Neuromuscular Versatility Though its Failure Modes

Francisco J. Valero-Cuevas
University of Southern California

Neuromuscular function has long been considered a shining example of successful brain-body coevolution for versatile function. So much so that it has repeatedly been an inspiration to successive generations of engineers seeking to build versatile machines. But the question remains: what are the specific neural or anatomical features and interactions responsible for such functional versatility? Some of our work in the human hand begins to answer that question by taking an alternative tack: Why is it that even mild neurological conditions or physical injury lead to measurable disability? I will present recent work revealing some limits of functional performance. For example, while theoretically redundant, skeletal musculature is actually not robust to dysfunction or loss of even a few muscles (be it in a finger or a limb). In addition, the cortical networks that support and enable dexterous manipulation are exquisitely context-dependent, take decades to mature, and are quite vulnerable to the aging process. Even the production of simple finger flexion movements requires a complex and critically timed interaction among tendon excursions and muscle forces. These separate lines of evidence suggest that the functional versatility of the hand is continually on the verge of failure. Understanding those failure modes begins to (i) identify the specific brain-body features and interactions responsible for functional versatility, and (ii) dispel the apparent paradox between our theoretical reverence for hand function and the clinical reality of hand disabilities.
Task-level Control of Unsteady Locomotion in Humans

Devin Jindrich and Mu Qiao
Arizona State University

Research on the mechanics, energetics and motor control of locomotion has primarily focused on constant-average-velocity walking or running. However, for humans or other animals in natural environments, sustained steady locomotion is less common than unsteady locomotion involving maneuvers or compensations to maintain stability. We are conducting experimental studies of sagittal and horizontal-plane maneuvers to better understand the task-level control of unsteady locomotion. In the sagittal plane, the task-level strategies used for body control during running appear to be consistent with the strategies employed by bouncing robots with sprung telescoping legs. Changes to running height were associated with changes to leg force but not stance duration. To change speed, humans primarily used a "pogo stick" strategy, where speed changes were associated with adjustments to fore-aft foot placement, and not a "unicycle" strategy involving systematic changes to stance leg hip moment. However, hip moments were related to changes to body orientation and angular speed. Hip moments could be described with first order proportional-derivative relationship to trunk pitch if a time lag of 82 ± 28 ms consistent with programmed responses was included. Future perturbation experiments will help determine whether these strategies reflect independent feedback rules similar to those effective for robots. Experiments on maneuvers in the horizontal plane (turns) suggest that step mechanics are adjusted to maintain comparable initial kinematic conditions for each step. Humans wearing a pack that increased yaw rotational inertia 4-fold continued to generate braking forces to prevent over-rotation due both to lateral turning forces and also initial angle and rotational velocity. Future experiments will determine the relationship between proactive maneuvering strategies and reactive compensations used to maintain stability.

Sang Hoon Yeo¹, Dinesh K. Pai¹, Jenna Monroy², Theodore A. Uyeno², & Kiisa C. Nishikawa²

¹University of British Columbia
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Numerous studies have suggested that the giant, elastic titin protein plays a role in active muscle contraction, but such a role remains to be demonstrated. We developed a two-step “winding filament” hypothesis for the role of titin in active muscle. The hypothesis proposes that titin is first engaged mechanically during Ca²⁺-activation, and the cross-bridges then wind titin on the thin filaments, storing elastic potential energy during isometric force development. Energy stored in titin during active stretching contributes to the low cost of force enhancement, whereas unwinding of titin explains the velocity dependence of force depression during active shortening. By regulating the rate of recovery of elastic energy from titin in a load-dependent manner, the cycling cross-bridges endow active muscle with intrinsic stability to perturbations in load. Based on this hypothesis, we developed a relatively simple, constitutive “winding ratchet” model that accounts for the non-linear, history-dependent force output of muscle. The “winding ratchet” model out-performs Hill-type muscle models in predicting muscle force in isovelocity experiments, in which the non-linear behavior of muscle is prominent. The “winding filament” hypothesis and “winding ratchet” model have significant potential for explaining and simulating muscle’s contributions to motor control. The hypothesis and model also suggest biologically inspired designs for actuators and prostheses that more realistically mimic muscles by providing non-linear history-dependent force output and instantaneous adaptation to perturbations in load.
Model-Based and Model-Free Mechanisms of Human Motor Learning

Adrian Haith, John Krakauer
Johns Hopkins Hospital
Department of Neurology

Motor learning is often described in terms of a systems identification problem, whereby an internal model of the plant or environment must be learned or updated through experience. This internal model is then used to guide planning and control of movements. This framework has proven very successful in explaining many features of behavior in adaptation paradigms (force fields, visuomotor rotation, etc.). I will argue, however, that not all motor learning occurs through such model-based mechanisms. I will argue that there exist alternative learning mechanisms that operate independently of internal models and instead rely on direct reinforcement of successful actions to improve control. These model-free learning mechanisms may constitute a substantial component of learning in conventional adaptation paradigms. I will show examples of phenomena in both visuomotor and force field adaptation tasks that cannot be explained within model-based frameworks, but are entirely consistent with idea of learning via model-free reinforcement of successful actions.
How is the Rate of Motor Learning Determined?

Maurice Smith
School of Engineering and Applied Sciences & Center for Brain Science
Harvard University

The human motor system has the remarkable ability to not only adapt the relationship between goal and action, but also to modulate the rate at which this relationship is adapted. We studied this adaptation rate modulation during goal-directed reaching movements in novel dynamic environments. Previous work has suggested that adaptation rate modulations may arise from changes in the way that motor errors are estimated from noisy sensory information. However, here we show that changes in expectations about the persistence of environmental perturbations play a crucial role. Environmental perturbations can alter our actions and lead to motor errors, but adaptation to these perturbations can only be effective if they persist from one movement to the next – suggesting that the degree of persistence should strongly modulate the rate of motor adaptation. We tested this idea by altering the consistency of force-field environments, and found dramatic learning rate changes. We were able to downregulate adaptation rates by over five-fold and upregulate them by over three-fold - a range encompassing over one full order of magnitude (18x). We show that the observed adaptation rate changes cannot be explained by perturbation size estimation, the amount of training received, or by a savings mechanism, and that changes in predictions about the persistence of environmental changes may provide a mechanism for structural learning and are likely to account for several instances of learning rate changes that were previously attributed to state noise modulations.
Cognitive Neuroscience of Skill Learning

Rachael D. Seidler
University of Michigan

I will discuss my recent work delineating the precise nature and neural correlates of the cognitive processes that contribute to skill learning. I have demonstrated an important role for spatial working memory in the two major types of motor skill learning: sensorimotor adaptation and motor sequence learning. Working memory refers to a system for maintenance and manipulation of information in mind over a period of several seconds. I have shown that spatial working memory capacity is predictive of the rate of motor learning for both sensorimotor adaptation and motor sequence learning. I have also reported neural overlap between a spatial working memory task and the early, but not late, stages of adaptation. I propose that spatial working memory is relied upon for processing motor error information to update motor control for subsequent actions. I will also present new findings demonstrating that depletion of spatial working memory resources negatively affects the rate of early sensorimotor adaptation. In contrast, enhancing working memory capacity via a training intervention does not boost sensorimotor adaptation, suggesting that spatial working memory capacity may not be the factor limiting maximal rates of adaptation. I will discuss these findings from a resource limitation and capacity framework with respect to current views of skill learning.
Actions and Activations of Hindlimb Muscles in the Rat

Matt Tresch
Northwestern

The control of movement is a distributed process, involving both neural control strategies and musculoskeletal properties. We are currently pursuing investigations into both systems, in order to better understand biological motor control and leverage this understanding towards improving function following injury. We describe a set of related experiments examining these issues. First, we examine the degree of specificity and flexibility in spinal pattern generators, assessing whether the pattern generators at birth are capable of differentially activating intramuscular subdivisions in the complex hindlimb muscle biceps femoris. Second, we describe a novel approach for creating a musculoskeletal model to capture the mechanical actions of individual muscles and evaluate its ability to capture the action of both simple and complex muscles in the rat hindlimb. Finally, we describe our recent efforts at controlling the rat hindlimb through direct muscle stimulation. We have developed an experimental system to perform isometric force control with a large number of muscles and applied probabilistic methods to improve the accuracy of control. With this preparation we can evaluate proposed biological control strategies directly, both as potential strategies for neural control and as strategies for restoring movement following spinal cord injury. Together, these experiments allow us to examine this process of distributed motor control, characterizing the contributions from neural and musculoskeletal systems.
Symposium: Spinal cord  
Friday July 22nd  
3:30 PM –5:00 PM

Role of Spinal Circuitry in the Control of Goal-Directed Movements

Dick Poppele  
University of Minnesota

There are a number of basic problems the nervous system must solve in order to control goal-directed movements, and it is generally understood that supraspinal circuitry is required in order to solve them. One is that information may need to be re-mapped from sensory to motor coordinates. For example, somatosensory information may be organized within a reference frame describing the locations of receptors in the body surface. However, the motor output is organized in a reference frame of the muscles and joints. Thus sensorimotor coordination generally requires a transformation across reference frames. In addition, goal directed movements are most likely specified in terms of their kinematics, i.e. positions and velocities in space, whereas motor commands to the muscles specify muscle contraction forces instead. The computational capacity needed to specify muscle forces required to move a multi-jointed limb along a particular trajectory to a specified location can be quite significant, and not expected from the spinal circuitry alone. Moreover, there are infinitely many ways in which a multi-jointed limb can be manipulated to achieve any given endpoint position, so the control problem may also have many solutions. It is generally assumed that the solutions of control problems such as these are carried out by supraspinal circuitry. However, spinal cord circuits do contribute to the management of these functions and they have been shown to be responsible for coordinated movement control in spinalized animals. A well-known example is the wipe reflex exhibited by the spinalized frog, which is capable of directing a multi-jointed limb to an any specific skin location with unfailing accuracy. Therefore, while cerebral and cerebellar circuitry may play a role in solving these essential control problems, it is clear the vertebrate spinal cord circuitry can also carry out these functions in the absence of supraspinal support.
The role of GluA1 and SAP97 in Motor System Development

Robert Kalb
Children's Hospital-Philadelphia

Motor neurons develop their mature structure and function over an extended period of prenatal and early postnatal life. Synaptic activity plays a crucial role in this acquisition process. We have studied the role of glutamate receptor genes in the development of the motor neuron dendritic tree, the pattern of connections within the segmental spinal cord and locomotor behavior. We have found that the GluA1 subunit of the AMPA-subtype of glutamate receptors is expressed at very high levels in early postnatal life. Over the subsequent month, the abundance of the message and protein in motor neurons falls dramatically. During this period the motor neuron dendritic tree doubles in size. We took two approaches to determine if these events are linked. First, we studied motor neurons that lack GluA1. Both in vitro and in vivo, motor neuron dendrite elaboration is stunted in the absence of GluA1. Second, we over expressed GluA1 in motor neurons (as well as other spinal cord neurons) and found that this leads to large scale remodeling of the dendrite tree. This effect depends on the electrophysiological properties of the AMPA receptors assembled with GluA1. Using pseudorabies virus tracing we found that the pattern of interneuronal connections with motor neurons is perturbed in mice that do not express GluA1 and this is associated with a variety of defects in locomotor function. To understand the mechanism by which activity of AMPA receptors assembled with GluA1 is translated into dendrite growth, we focused synapse associated protein of 97 kDa molecular weight (SAP97). SAP97 is a scaffolding, postsynaptic density protein that is the only known binding partner of the extreme carboxy terminus of GluA1. Using a variety of genetic tools we have found that all of the pro-dendrite growth effects of GluA1 are mediated by SAP97. This work indicates that GluA1/SAP97 are required for the normal activity-dependent development of the motor system.
I will address the ancient problem of why is it so difficult to rub your stomach while patting your head. While this task is somewhat difficult to control in the laboratory, variants have been well-studied in the motor control literature, designed to provide insight into our competence and limitations in the production of actions. The emphasis in this literature has been on constraints related to motor programming and execution. I will offer an alternative framework, arguing that many of the constraints require consideration of the representation of the task goals. These ideas will be developed by reviewing work from two lines of research. The first builds on the literature on bimanual rhythmic movements. The behavior in such tasks has been elegantly described by dynamical models such as that based on coupled oscillators. However, the relationship of these models to underlying psychological processes remains unclear. I will present a model in which an important limiting factor in temporal production relates to the representation of salient temporal events that define the task structure. The second domain looks at spatial constraints on bimanual movements, asking why people have difficulty producing simultaneous movements that follow non-parallel trajectories. Here a cognitive perspective provides a link between bimanual coordination and dual-task performance, highlighting the limited nature of processes involved in response selection rather than movement execution. In summary, in both the temporal and spatial domain, I will focus on process-oriented hypotheses, arguing that fundamental constraints arise at a cognitive level, reflecting the manner in which the task goals are represented. This perspective allows us to see how qualitative changes in performance can emerge, even when there are very subtle differences in the movements themselves.
Theoretical and Methodological Issues in Serial Correlation Analysis

Didier Delignières, Vivien Marmelat & Kjerstin Torre
EA 2991, Movement_to_Health, EuroMov, University Montpellier I, France

The aim of this communication is to evoke some theoretical and methodological problems related to the analysis of serial correlations in experimental time series. A very common observation in behavioral and physiological experiments is the presence of long-range correlation in time series. In this case the current observation seems to keep the memory of large set of previous observations. This kind of process has been referred to as long-range dependence, long-term memory, fractal correlation, or 1/f noise. There is now a general agreement for considering long-range correlations as reflecting the complexity of the system, defined as the flexible and adaptable coordination between its multiple components and sub-systems. Long-range correlations are supposed to sign an optimal compromise, between order and disorder, order reflecting a too strict and rigid coordination, and disorder the absence of coordination. Long-range correlations are considered the signature of health and adaptability, and deviations towards order and disorder have been described in elderly or pathological populations. As such, the detection of long-range correlations and the assessment of their alteration in specific populations or situations appears as an important scientific goal. However, the detection of long-range correlation in empirical series is not straightforward. A number of recent experiments have showed that the pattern of correlation observed in empirical series has to be considered as a combination of short-range and long-range correlation processes. This is important because apparent alterations in long-range correlations could in fact be due to the superimposition of short-term correlation. An additional problem is that short-range correlation processes can sometimes mimic long-range correlations. Classical methods, such as Detrended Fluctuation Analysis or Power Spectrum Density analysis, seem unable to distinguish between short- and long-range correlated processes. Some specific methods have been developed for testing for the effective presence of long-range correlation in series.
A Mathematical Approach from Motion Analysis to Spinal Reflex Modeling

Yoshihiko Nakamura*1, Akihiko Murai*2, Yuki Ibuka*1

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Recent technology for motion analysis of human behavior allows synchronized constraint-free and high-bandwidth measurements of the whole body motion, contact forces, and wireless EMGs of representative muscles. How far can we approach internal information and internal sensation of human body based on such invasive measurements? This paper discusses a mathematical approach to model the spinal reflex in human motion. The motion skill of top athletes as well as the immediate response to unexpected contact and collision of senior persons would not be explained without the role of spinal reflex. The anatomical knowledge of the musculoskeletal biomechanics and the neural projection of the spinal nerve to the skeletal muscles is used as the foundation of modeling. A pure mathematical neural network is assumed for the model of biological neural network inside the spine and trained to minimize the error of muscle activations for a set of collected motions. The assumption is posing a hypothesis that the synaptic connection in the spine between the afferent and efferent motor neurons is formed in the evolution and development to minimize the motion error and to best use the biomechanics of the body. Some computational examples are to be shown for discussion. We have recently worked to add the skin reflex model, which is also briefly introduced in the presentation.
A number of objects that we manipulate every day are inherently unstable. While much of motor learning has focused on the learning of sequences, force-fields and limb dynamics, much less is understood about how we learn to control unstable objects. Skills such as riding a bicycle, balancing a stick or a hula-hoop require the learning of task-specific control principles. In such tasks, even a slight change in circumstance leads to disproportionate loss in performance stability. This talk will address the theoretical issues involved in the control of such unstable objects, using the paradigmatic example of stick-balancing. Five major ideas will be addressed 1) Changes in the statistical distributions that characterize stick-balancing with learning 2) Intermittent control dynamics in the context of motor learning 3) The role of attention on balancing performance 4) Coupling between stick-balancing and the postural system and 5) The organization of multi-joint kinematics in stick-balancing control. The discussion will focus on how intermittent control models can be constructed using principles of optimal feedback control and dynamical systems theory. Applications of the methodologies developed from these experiments for studying other stochastic systems will be addressed, with special reference to the control of the oculomotor system.
Symposium: Stochasticity & Intermittency
Saturday July 23rd
2:15 AM –3:45 PM

Intermittent Motor Control: The Interplay Between Noise and Delay

John Milton
The Claremont Colleges

A consequence of finite axonal conduction and integration times is that human reaction times are surprisingly long (100’s of milliseconds) and furthermore increase as the complexity of the task increases. The control of an unstable dynamical system, such as those that arise in the stabilization of an inverted pendulum, becomes problematic in the presence of random perturbations (“noise”) when time delays are long. The inherent problem is distinguishing those fluctuations that need to be acted upon by the controller from those which do not. This is because, by definition, there is a finite probability that an initial deviation away from the set point will be counter-balanced by one towards the set point just by chance. Too quick a response by a controller to a given deviation can lead to the phenomenon of “over control” leading to destabilization. On the other hand, waiting too long runs the risk that the control may be applied too late to be effective. Control theoretic arguments emphasize that when time delays cannot be compensated using internal model estimates then the optimal control strategy is an intermittent one, i.e. corrections are made only when deviations become large enough to interfere with task performance. Several observations suggest that a variety of intermittent control strategies occur in the setting of human balance control including on-off intermittency in stick balancing, the appearance of multiple scaling regions in the fluctuations in human postural sway during quite standing, and the unexpected beneficial effects of periodic vibration for the transient stabilization of both stick balancing and human postural sway. The possibility that switch-like controllers arise in balance control suggests that the nervous system may ultimately choose control strategies that minimize its energy expenditures.
Stochastic Systems with Statistical Feedback:  
On a Model for Postural Control  

Andreas Daffertshofer  
Research Institute MOVE, VU University Amsterdam, The Netherlands

Random noise is omnipresent in motor behavior. In this talk, the mathematical framework of stochastic differential equations will be briefly recapitulated and applied to the problem of balance control. Importantly, balance control possesses the ability to adapt quickly and adequately to both environmental and internal changes by emergence and disappearance of attractor states. This vital ability cannot be explained in terms of conventional stochastic processes because it is characterized by a trade-off between flexibility and accuracy. As such, balance control appears particularly hard to tackle, also because it requires the incorporation of both finite delays in the dynamics and somewhat exotic stochastic features that fall in the realm of fractional Brownian motion which display self-similarity with correlations obeying power laws. Postural sway during quiet stance will here serve to illustrate effects of noise that is multiplied with the probability density of the underlying stochastic dynamics. These dynamics do exhibit power law characteristics that have been reported in time series of the center-of-pressure during quiet stance. The coupling between the probability density and every individual random realization may be seen as statistical feedback that can be assessed using generalized entropies and nonlinear Fokker-Planck equations. Interestingly, these dynamics are closely related to stochastic dynamics with delay(s) since a feedback if the probability density is estimated using a finite-size buffer to memorize a single realization’s short-term history.
Theory of Action-Perception for all Organisms: What kind of Science does it Entail?

Michael T. Turvey
Center for the Ecological Study of Perception and Action, University of Connecticut and Haskins Laboratories

I will highlight the argument that the requisite theory of action and perception should apply to all organisms, the 96 phyla that comprise the Five Kingdoms—Bacteria, Protoctista, Animalia, Fungi, and Plantae. The major barrier to implementing such a theory is the traditional incommensurability of psychology, biology, and physics. The incommensurability encourages taking loans of intelligence and deters seeking explanation from first principles. A science founded on commensurability is required. I will discuss some of its challenges.
**Poster Session 1**  
**Thursday July 21st**  
**1:15 PM – 2:15 PM & 4:00 PM – 5:00 PM**


102: The Role Of Musical Expertise In Circle Drawing And Finger Tapping. *Lawrence Baer, Marc-Olivier Hamel-Doyon, Li Karen, Penhune Virginia.*

103: Motor Skills Affects Ground Reaction Force Absorption. *Angelo Bartsch, Cristián Cuadra, Juan Yañez.*


105: Effect The Dart Weight And Target Distance On The Kinematic Variables Of The Movement Control Of The Underarm Throw Task. *Carlos Eduardo Campos, Rodolfo Novellino Benda, André Gustavo Pereira Andrade, Cristlaine Rangel Couto, Vitor Leandro De Silva Profeta, Herbert Ugrinowitsch.*

106: Reaching And Grasping Behaviors In Infants With And Without Neonatal Stroke. *Chen Chao-Ying, Heathcock Jill.*

107: Postural Facilitation Of A Precision Task At Sea. *Fu-Chen Chen, Thomas Stoffregen.*

108: Control Of A Video Game Avatar Influences Motion Sickness And Postural Activity. *Yi-Chou Chen, Xiao Dong, Jens Hagstrom, Thomas Stoffregen.*


113: An Assessment Of Gait And Balance After Vestibular Rehabilitation Therapy In Elderly With Vertigo. *Flávia Doná, Juliana Quirino Thomaz, Denise Alves Dos Reis Maia, Juliana Maria Gazzola, Cristiane Akemi Kasse.*


117: Trunk Inter-Segmental Coordination And Functional Gait In Stroke. Revital Hacmon, Tal Krasovsky, Anouk Lamontagne, Mindy Levin.

118: Continuous Energy Margins And End-State Accuracy In The Control Of Objects With Complex Dynamics. Christopher Hasson, Tian Shen, Dagmar Sternad.


120: Motor Adaptation To Repeated Obstacle Crossing During Locomotion. Michel Heijnen, Brittney Muir, Shirley Rietdyk.

121: Slow Oscillations In The Internal Segment Of Globus Pallidus Predict Reaction Times And Lead Cortex Prior To Errors. Maria Herrojo Ruiz, Julius Huebl, Thomas Schoeneberg, Gerd-Helge Schneider, Andreas Kupsch, Joachim K. Krauss, Andrea A. Kuehn.


126: A Comparative Study Of Bipedal Locomotion Of Humans And Japanese Macaques From The Viewpoint Of Leg Joint Synergy. Shoko Kaichida, Yoshimitsu Hashizume, Naomichi Ogihara, Jun Nishii.


Two Stages Of Feed-Forward Postural Control: Early And Late Postural Adjustments. Vennila Krishnan, Alexander S. Aruin, Mark L. Latash.


Inter-Subject Differences In The Control Of Movement Variability. Melanie Krüger, Thomas Eggert, Andreas Straube.


Grip Force Control Modulation Due To Load Change In Individuals With Carpal Tunnel Syndrome. Daniela Mattos, Susana Domenech, Noé Borges Jr., Marcio Santos.

Complementary Rhythmic Joint Action: Dynamics Of An Interpersonal Collision-Avoidance Task. Ryan A. May, Steven J. Harrison, R. C. Schmidt, Michael J. Richardson.

Individual-Specific Variability In Action-Perception Coordination Is Revealed At Around Critical Frequencies. Akito Miura, Kazutoshi Kudo, Kimitaka Nakazawa.

Semg Biofeedback In Aquatic Physical Therapy As A Therapeutic Toll Directing The Exercise Choice In Stroke. Camila Mottinelli De Souza, Alexandre Lara Moraes, Valmir Baccaro, Mirna Kanashiro.


A Muscle Model Including A Distributed Implementation Of The Equilibrium Point Hypothesis: Application To Face Movements. Mohammad Ali Nazari, Pascal Perrier, Matthieu Chabanas, Yohan Payan.


Aging Reduces Learning Benefits As Result Of Bilateral Transfer. Zhujun Pan, AREND VAN GEMMERT.


Serious Gaming To Improve Bimanual Coordination In Children With Spastic Cerebral Palsy. Lieke Peper, Edwin Van Loon, Anke Van De Rijt, Annelie Salverda.

Humans Are Asymmetric During Natural Standing But They Do Not Have A Preferred Leg For Standing. Janina Prado, Raquel Castanharo, Mayra Vilela, Marcos Duarte.


152: Gait Dynamics In Trans-Tibial Amputees When Using Different Prosthetic Ankles. Christopher Rhea, Alan De Asha, Louise Johnson, John Buckley.


154: A Relationship Between Hand Function And Grip Force Control In Individuals With Hands Osteoarthritis. Marcio Santos, Paula Martins, Diana Oliveira, Alexandre Aruin.


156: Changes In Perception-Action Coupling Influence Postural Sway And Motion Sickness. Leonard Smart, Edward Otten, Adam Strang, Eric Littman.

157: Violin Bowing: The Use Of Redundancy In The Mapping Between Mechanical And Acoustic Task-Spaces By Expert Violinists. Peter Stein, Diana Young, Jack Dennerlein, Joann Kluzik, Hosung Nam, Elliot Saltzman.


159: Incrementing COP Data Prior To Time-Series Analysis Improves Delineation Of Age-Related Changes In Postural Control. Adam Strang, Angela Didomenico, William Berg.


166: The Minimal Adhesion Area In Fingertip-Surface Interaction. Alexander V. Terekhov, Vincent Hayward.


201: Asymmetries In Force Control And Sense Of Effort. Diane Adamo, Samantha Scotland, Bernard Martin.


204: Task Dependency Of Electromyographic Amplitude In Vastus Lateralis And Obliquus. Angelo Bartsch, Cristian Cuadra, Andrés Dintrans, Veronica Reyes, Alejandro Lagos.


206: Postural Responses To Suprapostural Tasks In Children With And Without Developmental Coordinat. Fu-Chen Chen, Michael Wade, Chia-Liang Tsai, Thomas Stoffregen.


212: Contradictory Effects Of Interhemispheric Inhibition On Unimanual And Bimanual Control. Brett Fling, Rachael Seidler.


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