Tamar Flash

Tamar Flash is a Full Professor at the Weizmann Institute of Science in Israel and pioneer of motor control science.

She earned her BSc and MSc degrees in physics from Tel Aviv University. For her PhD studies she studied at the Harvard-MIT division of health sciences and technology and conducted her PhD thesis research in motor control under the supervision of Prof Emilio Bizzi receiving her PhD in medical physics from the Massachusetts Institute of Technology in 1983. She carried out her postdoctoral training at MIT till 1985. She then established a research group at the Weizmann Institute, where she has also served as head of the board of studies and of the Department of Computer Science and Applied Mathematics. Flash was a visiting professor at MIT, the College de France, UC Berkeley and a fellow of the Radcliffe school of advanced studies, Harvard University. In 2016, she was elected as a foreign member of the American Academy of Arts and Sciences.

The influence of Bernstein on the scientific career of Dr. Flash is summarized below.

Somewhat on the personal side I have to admit that I owe a large part of my decision to study movement control by the brain to the incidental encounter or the great luck I had, of finding the little book by Bernstein "On the coordination of movement" which was translated and appeared in English in 1972. By coincidence, I found the book by Nikolai Bernstein in the Physics library at Tel-Aviv University, I started reading it, still at the library, borrowed it without knowing anything about who Bernstein was and finding it so fascinating that I decided to start studying the field of motor control while still being in Israel. Later after moving to MIT and being enrolled in the Harvard-MIT Health Science Program, I attended the lectures on motor control, given by Professor Bizzi in the Foundations of Neuroscience course. Then, I indeed decided to focus on motor control studies in my PhD thesis research work. I then learned that Prof. Nikolai Bernstein was very well respected and had a large following that strongly influenced the research directions that the motor control field had taken during that period in both Europe and the USA. Bernstein's work has had a growing influence on scientific thought in motor control as captured by the book - Bernstein reassessed, edited by Whiting (1983).

In particular, my focus in trying to develop computational models and formulate theories on the planning and control of hand trajectories, as manifested in the joint work carried with Prof. Neville Hogan from MIT, were inspired by the ideas expressed by Bernstein in his book, namely:

"There exist in the higher levels of the central nervous system projections of space, and not projections of joints and muscles. (Bernstein, 1935)"

Many of research topics that I have pursued were indeed highly influenced and inspired by Bernstein’s writing, namely that "There is considerable reason to suspect that in the higher motor centers of the brain (very probably in the cortical hemispheres) the localization patterns are nothing other than some sort of form of properties of the external space in the form present for the subject in the motor field. This project must be congruent with external space but not topologically and not metrically (Bernstein, 1935)". My recent focus on trying to infer what geometries, Euclidean and non-Euclidean, underlie the planning of end-effector trajectories both of the hand, in the case of the upper limb, and of the center of mass for human locomotion, do indeed align with Bernstein concepts and suggestions that the internal representations of movement are congruent with the motor output, i.e., the hand or center of mass trajectories but neither metrically (not being Euclidean congruent with the produced movement) nor topologically.

Other research studies in which I have been influence by Bernstein's ideas are related to motor execution in face of the complicated nature of movement dynamics and biomechanics. One topic on which I have focused early on in my studies was the presence of interaction torques, i.e, centripetal and Coriolis forces which are present in any multi-joint movement, be it of a natural or an artificial limb (Hollerbach and Flash, 1982). Bernstein has stressed that a long period of time (roughly 12 months) is needed for human infants to develop and master the skill of walking because of the complexity associated with overcoming or compensating for the effects of gravity and interaction torques. Another focus of my research has been on modeling the equilibrium trajectory control scheme, studies inspired by the works of Feldman, Bizzi and Hogan, but whose origin can be traced to Bernstein's suggestion that the control of posture and movement is based on controlling equilibria among forces generated by antagonistic muscles or muscle synergies and by controlling limb stiffness around the equilibrium position.

Then, of course, over the last twenty years I have dealt and addressed again and again the degrees of freedom problem defined and investigated in many studies by Bernstein, and later on by Latash, Scholtz, Schonner and along different directions by Feldman and Levin, or by Mussa-Ivaldi and Hogan.

My students, colleagues and I have investigated related issues first in our studies of the control of three dimensional arm movements when it is needed to resolve or take advantage of kinematic redundancies (see the papers by Gielen, Liebemann, Biess, Berman etc). Similarly in recent years we have started investigating the nature of motor coordination and the resolution of kinematic redundancies during human locomotion, i.e., developing a simple model based on oscillatory patterns of lower limb segments (Barliya et al. 2009) and accounting for the intersegmental plane of coordination as discovered and described by Lacquaniti, Ivanenko and colleagues. Finally, two other threads that go through my entire research and which were definitely inspired by Bernstein’s work are the hierarchical organization of the motor system from more abstract, higher level of representation, to more concrete representations of motor commands to the muscles and the importance of discovering motor invariants. Along the latter line of research we investigated the existence of motor invariants by combining both behavioral studies and developing mathematical and computational models enabling us to describe such spatial and temporal invariants. Among these one can include both earlier studies indicating the temporal scaling of the speed profiles of limb trajectories, or the work conducted in collaboration with Handzel, Polyakov, Bennequin, Berthoz, Fuchs, Meirovitch and Karklinsky using Non-Euclidean geometries to develop a theory of motor invariance (Bennequin et al., 2009) or to describe the relations between equi-affine invariants and the two-thirds power law. Also in relation to these behavioral studies I should mention neurophysiological, brain mapping and EEG recording studies (Zeharia et al., 2012, Kadmon-Harpaz et al., 2012, Dayan, sella and colleagues) aimed at identifying the neural substrates enabling invariance to size scaling as well as obeying various kinematic laws of motion in both action production and perception (Dayan et al., 2007, Casile et al. 2010, etc).