Adaptive Model Theory: A History

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Our accompanying presentation overviews the constructs of Adaptive Model Theory, a computational account of human movement control that has evolved over a research lifetime that began in the 1950s. Its origins are in the fascination of two young people with the prospect of applying their training in physics, mathematics, and engineering principles to the modelling of biological systems. Unlike today, it was an era in which such interdisciplinary work was rare and the path to undertaking it was essentially of one's own making. In this presentation we explore some of the history of that journey. There was the getting of technical jobs in UNSW's newly established medical school to provide a gateway to the biological world; the finding of labs where "way-out" ideas were tolerated, if not entirely understood; and the support for part-time graduate research. Not to mention the finding of unmeetable mentors accessible only via the literature.

Experimental work began with studies (without benefit of automated A-D conversion) into investigating the human tonic stretch reflex, not during rest as was usually done, but by modelling the input-output characteristics during voluntary contraction. From these followed a string of experimental investigations to investigate movement disorders, cerebral palsy in particular, but also Parkinson's disease, stroke, cerebellar disorder, and stuttering. At the time the latter was still widely believed to be psychological in origin. The voluntary movement tracking experiments carried out to model the input-output characteristics of the auditory-motor loop in stuttering and non-stuttering subjects gave strong credence to the now-accepted neurological basis of the disorder. Likewise, following on from the studies of reflexes in cerebral palsied subjects, experimental use of tracking paradigms to separate voluntary and involuntary activity in the purposive movements of this group showed a clear result which is now well accepted clinically. Quite apart from unwanted reflex activity, cerebral palsied subjects lack the ability to generate appropriate movements for a voluntary task, despite a cognitive understanding of what is required. In each of the neurological disorders we studied the experimental evidence pointed to deficits in the formation, maintenance and/or selection of the adaptive sensory-motor models underlying the forward control of voluntary movement.

Hence enter Adaptive Model Theory and the quest for a more general understanding of how the brain achieves control of the inherently nonlinear, nonstationary, uncertain, redundant, unstable system that implements human movement. In parallel with the theoretical development came more experiment, now mostly with normal subjects. This included examination of control-display compatibility in tracking, acquisition of tracking skill with practice, tracking with differing degrees of freedom, tracking with unusual systems that variously involved gain change, cross-coupling and instability, as well as investigations of predictability in tracking and the response planning strategies that apply. And of course there were the simulations that necessarily accompany the experimental findings and so guide the theoretical evolution. This ultimately has encompassed an account of motor development from the foetus to the mature system. So where now? It's a long way today from recognising that we can learn about biological systems by modelling their inputs and outputs. A great deal has been done, and not least in understanding the principles of sensory-motor control. But it's far from done yet. The mathematics of Riemannian geometry currently offers a new window into the planning of responses of complex systems. Therein lies a future understanding of human movement and its disorders.

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