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MOVEMENT VARIABILITY: A PERSPECTIVE ON SUCCESS IN SPORTS, HEALTH AND LIFE

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In Murphy's Law, book two,¹ Berman's statement "One man's error is another man's data!" provides a more optimistic corollary to Robert's axiom, "only errors exist!". Historically, variability has been considered as error in the system. From this view, it is important for error to be eliminated, and the lower the amount of variability in data, the better. Baida et al.² demonstrate that in 64% of the cases reviewed, increased variability exists in persons with musculoskeletal injury as compared to uninjured persons. The authors concluded that "deviations from normal ranges of movement variability" (i.e., either too little or too much variability) may be related to risk of injury due to improper neuromuscular control, providing a more comprehensive interpretation of amount of variability. On the other hand, understanding the structural properties of the such variability or fluctuations within movement provides different information and interpretations. Nikolai Bernstein first noted that variable trajectories (or fluctuations) in a movement could ultimately lead to the same solution in motor output and thus fulfil the same task goal, leading to the "degrees of freedom" or the redundancy problem.³

Human movement variability has been defined in many ways throughout literature. The majority of these definitions fall into one of two different approaches. One is that variability is the amount of variance; a deviation from the mean. The amount of variability is typically quantified through standard statistical methods such as standard deviation and coefficient of variation, sometimes referred to as linear measures. The second approach is that fluctuations throughout the movement are meaningful and have order within their structure. The complexity, predictability, divergence, and self-similarity of these fluctuations have been quantified through various measures. Referred to as nonlinear measures, these include, but are not limited to Lyapunov exponent, detrended fluctuation analysis, and entropy. It is important to note that when discussing variability, a clear distinction between the two approaches is critical as, although complementary, they are conceptually different.

Investigations into variability and fluctuations have spanned the breadth of movement analysis. These include motor development, motor learning, rehabilitation, injury, and sport. The presence of movement fluctuations reflects a healthy system's ability to adapt to ever-changing constraints within the environment. If fluctuations are either too predictable or

unpredictable, it affects system adaptability. Many times, these fluctuations have been interpreted in terms of complexity, the characteristics of which include interactions between and within multiple systems, and evolution in time, revealing information about the control processes. Motor skill maturity and healthy behavior are associated with optimal complexity.

Although in many cases we have embraced the concept of variability in human behavior as an essential ingredient of motor control, development and learning, our societal attitudes are still directed towards ignoring the essential implications of this variability. In sports, we emphasize practice variability to gain expertise in highly focused areas of expertise, in rehabilitation, a similar variability in practice is also emphasized towards regaining specific functions and a similar approach is applied for learning and development in children. Potentially, this is not what nature intended. The survival of the cockroach, for example, demonstrates a high degree of flexibility and adaptability to ever-changing environments. Possibly this is the reason why we possess variability - to be successful in different environments. Take, for example, the difference between a specially-trained, military soldier and an elite-level runner. For the runner, their diet, exercise, physiological measures, etc. are all regulated with the goal of reduction in time for their run. However, for the soldier, their goals being unknown at the time of training, their practice is diverse with many goals in mind. An interesting phenomenon is that specially trained soldiers have diverse anthropometrics while elite athletes all seem to share similar anthropometrics in specific sports. Thus, Bernstein's observation of human movement variability is essentially a degrees of freedom problem only if the objective is specificity of movement expertise. However, if the objective is one of adaptability or flexibility, such variability could be the key to success in health and life.

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