Movement System Variability, Keith Davids, Simon Bennett, Karl Newell, eds., Human Kinetics Press, Champaign, Ill., 2006. [My comments are contained in brackets.]

Chapter 3. **The Interface of Biomechanics and Motor Control**
Dynamic Systems Theory and the Functional Role
of Movement Variability

p.49f. Traditionally, movement variability has been considered a dysfunctional aspect of human motor behavior directly related to the amount of noise – random fluctuations that compromise the deterministic relation between input and output at different levels of analysis – in the sensorimotor system (Newell and Corcos, 1993; Slifkin and Newell, 1998).

p.50. However, the introduction of non-linear dynamics and chaos theory into the study of biological systems...has prompted motor control theorists to suggest that movement variability may occupy a functional role in human motor behavior. Indeed, recent evidence from research based on dynamic systems theory strongly supports the notion that movement variability is an essential feature of human motor behavior that affords the sensorimotor system the flexibility and adaptability to operate efficiently in a variety of performance, development and learning contexts.

Movement Variability: Traditional and Contemporary Approaches

p.50. Empirical studies have been dominated by outcome measures obtained from sensorimotor tasks requiring the use of a single biomechanical degree of freedom.

As skilled motor performance id often characterized by low variability of outcome measures...., it follows that the skilled motor performance is also characterized by highly consistent patterns of movement. Therefore, movement variability has been considered as a problem in the sensorimotor system that should be eliminated.

p.51 …..studies by....investigating the accuracy of aiming in pistol shooting, it was found that compensatory movements of the arms enabled skilled marksmen to reduce the variability in the spatial orientation of the pistol barrel. In contrast, novice marksmen were unable to demonstrate such compensatory movements and therefore exhibited greater variability in the spatial orientation of the pistol barrel.

In dynamic system theory, patterns of coordination emerge through generic processes of physical self-organization rather than being prescribed by some sort of executive regulating agent (Kelso, 1995).

A research strategy for proponents of dynamic system theory has, therefore, been to identify observable low-dimensional macroscopic variables – the so-called order parameters - that define stable and reproducible relationships occurring among the components of the sensorimotor system as it searches for and adopts functionally preferred states of coordination or attractor states.....When the sensorimotor system adopts a functionally preferred state of coordination, the dynamics of order parameters are highly ordered and stable, reflecting the capacity of the sensorimotor system to produce consistent patterns of coordination.

p.56ff. Interpretation of Movement Variability

In the past, sport biomechanists have rarely considered movement variability to be an important topic worthy of research attention in its own right. [Reasons for ignoring this aspect of movement] First: biomechanical analyses examining the kinetics of human motion have typically been inhibited by the design of equipment for motion analysis and the inefficiency of techniques for data reduction.... Second, the implicit assumption held by man sport biomechanists is that human motor performance is characterized by invariance in the motor system...., and therefore trial-to-trial variability has typically been deemed to have negligible practical significance. The assumption appears to have been perpetuated by the concept of motor programming that has dominated the movement sciences the past three decades.....Third, the frequent use of hierarchical models has encouraged sport biomechanists to adopt a reductionist approach in searching for performance parameters that contribute most to the performance criterion. However, these performance parameters do not provide any information about the underlying patterns of coordination that generate these performance parameters...The emphasis is very much out-oriented rather than process-oriented....Fourth, sport biomechanists often make the significant assumption that people share a common optimal pattern of movement...On the basis that highly skilled performers are likely to have 'more optimal' techniques that their lesser skilled counterparts, pooled group data are typically analyzed using inferential statistics to establish 'normative" values for specific performance parameters....a hypothetical ideal technique or motor template.

Dynamic Systems Theory Applied to Sport Biomechanics

Moreover, greater emphasis should be directed toward analyzing actual patterns of movement, instead of discrete kinetc measurements, as they provide a window into the underlying dynamics of the sensorimotor system.

p. 59. [Ex. Swimming]... to exemplify the functional role of movement variability, we examine the different strategies that might be used by swimmers to maintain optimum efficiency and effectiveness in relation to key performance constraints. We specifically focus on the effect of swimming speed on emerging patterns of coordination...From the perspective of dynamic system theory, any variability in movements patterns could be interpreted as reflecting the conscious or unconscious attempt to satisfy, in the best way possible, the unique confluence of constraints impinging on the swimmer – a process referred to as self-organizing optimality by Newell (1986).

p.60. Despite the clear need to understand how patterns of coordination are modified during a performance, this aspect of performance has rarely been examined in the literature. The main reason for the lack of attention appears to originate from the fact that most scientific investigations....have tended to adopt a reductionist approach and examine those descriptive stroke characteristics that are readily observable from the pool deck [cf. ski trail] such as swimming speed, stroke length and stroke frequency, rather than the actual patterns of coordination that produced them.....Small scale adjustments to the orientation of the hand based on changes in the 'feel' of the water may be made prospectively in skilled swimmer because of the tight coupling between the perception and movement sub-systems. However, large-scale changes in whole body patterns of coordination may be necessary to maintain optimal efficiency and effectiveness, particularly with the concurrent increase in resistive drag forces experienced by the swimmer. It is feasible that a non-equilibrium phase transition or bifurcation, characterized by a shift from one state of coordination to another by the swimmer, may occur. [ex. Human and equine gait]

p. 73. **Serving Up Variability and Stability**

It is argued that the implicit influence of the theory of linear systems on coaching theory has resulted in an over emphasis on consistent, repeatable, almost stereotyped [and thus imitated] movements. The idea that consistency in motor patterns should be the prime goal of practice organization and structure is rejected. Rather, when the dynamic relationship between performer and the environment is considered, variability clearly plays a key role in attaining consistent outcomes.

p. 80. Variability Can Provide a Basis for Practice in Parts

The dilemma of whether complex motor skills should be broken down into smaller parts or left as a whole for the purpose of practice has been one of the most enduring for those studying the acquisition of movement skills... few direct examinations of the topic with little support for the prediction that part practice regimes have positive transfer qualities.... Clearly the success of this approach rest on he assumption that the key factors that influence the dynamics of a skill are known *a priori.* Lintern (1991) casts serious doubt on this assumption, suggesting that significant limitations in current kowledge restrict the development of practical guidelines. The result is that many practices in sport are presently implementing methods that are at best based on unprincipled and tentative foundations. The problems with this area are neatly summarized by Newell (1981), who suggest that current practices are "not founded on strong evidence and theoretical interpretations of their effects are even more hazardous."

(Example. Comparing practicing a volley ball serve as a) toss only and b) whole serve.)
p. 82. If the change effected by task decomposition it too great, then the characteristic variability profile should be disrupted. In this case, the degree of interference determines the extent of the transfer, with significant changes possibly representing a fundamental shift to a coordination that is somewhat unrelated to that to be acquired. In other words, the constraints resulting from partitioning the task are so removed from the original task constraints that the goals of each movement are essentially different and imrpovements of the whole cannot be predicted.

p. 83. Conclusion – [favoring ecological, whole-body movement training]

A study of serving has demonstrated a clear case for reducing variance in certain influential parameters while sowing the fluctuations in other parameters are noncritical and perhaps even complementary. In fact, one interpretation suggests that practices designed to generally reduce variability in movement might ultimately prove to be detrimental to learning.