Letter to the Editor

On analysing and interpreting variability in motor output

A recent article in the *Journal of Science and Medicine in Sport* by Chapman et al.[1] reported data from an empirical investigation comparing lower extremity joint motions, joint coordination and muscle recruitment in expert and novice cyclists. 3D kinematic and intramuscular electromyographic (EMG) analyses revealed no differences between expert and novice cyclists for normalised joint angles and velocities of the pelvis, hip, knee and ankle. However, significant differences in the strength of sagittal plane kinematics for hip–ankle and knee–ankle joint couplings were reported, with expert cyclists displaying tighter coupling relationships than novice cyclists. Furthermore, significant differences between expert and novice cyclists for all muscle recruitment parameters, except timing of peak EMG amplitude, were also reported.

Perhaps the most theoretically interesting finding to emerge from this study was that novice cyclists exhibited significantly greater variability in hip–ankle and knee–ankle joint couplings than expert cyclists. From an information processing theoretical perspective, it could be argued that these results, taken at face value, support the proposition that motor learning is characterised by progression towards invariance in motor output[2] and that movement variability might be a negative by-product of noise in the central nervous system that should be minimised or eliminated.[3–5] However, from a dynamical systems theoretical perspective, observed variability in motor output in both novice and expert cyclists may not necessarily be a reflection of system noise. As motor learning from a dynamical systems theoretical perspective is considered to be the search for stable and functional states of coordination,[6] it is possible that the greater variability displayed by novice cyclists in the relative motion plots of Fig. 1(b) of Chapman et al.[1] may represent exploratory behaviour as the system attempts to discover stable regions of the 'perceptual-motor workspace' or attractor states[7] that subserve the production of functional, possibly optimal, coordination solutions. The much narrower bandwidth of motor variability exhibited by the expert cyclists could also be considered functional as it may represent subtle adaptations to continuously fluctuating constraints on action, or 'controllable chaos' as Kelso and Ding[8] described it.

There are a number of theoretical and methodological issues that need to be considered when attempting to establish the functionality and role of movement variability in motor control and learning. First, operational analyses, such as the one conducted by Chapman et al.,[1] need to be underpinned by a scientifically rigorous theoretical rationale that should form the basis for hypothesis testing and experimentation. Second, the theoretical framework adopted must also have the scope to consider alternative interpretations of motor variability, rather than making the default assumption that it is an artefact of noise in the system.[9] Third, the inverse relationship between movement variability and skill level is not universally supported in the literature with some studies actually showing *reduced* variability in less skilled performers compared to their more highly skilled counterparts [e.g., 10,11]. Similarly, the clinical literature has shown that patients exhibiting injury or disease, in some cases, exhibit *less* variability than healthy controls[12,13] although there can be an *increase* or *decrease* of variability depending on the intrinsic dynamics of the system and the constraints on action.[14,15] Finally, the recent introduction of non-linear measurement tools[16] in empirical studies have revealed that it is the *structure*, rather than the *magnitude*, of movement variability that appears to be of greater significance in understanding normal and pathological human perceptual-motor functioning.[17,18]

To summarise, it is proposed that observations of motor variability require careful consideration to establish its functionality and role during goal-directed movement. Clearly, the default interpretation that movement variability is synonymous with noise is no longer tenable. However, this is not to say that all motor variability is functional, but rather, that not all variability is dysfunctional. Empirical research should be firmly based on a theoretical framework, such as dynamical systems theory, that can underpin hypothesis testing and experimentation. Importantly, it is the *structure*, rather than the *magnitude*, of variability that is important in uncovering the functionality of this ubiquitous feature of human motor behaviour.

References

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Paul S. Glazier [*]
Centre for Sport and Exercise Science, Sheffield Hallam University, Collegiate Campus, Sheffield, UK
Keith Davids
School of Human Movement Studies, Queensland University of Technology, Australia
[*] Corresponding author.

E-mail address: paul@longdrivegolf.co.uk (P.S. Glazier)

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