ON THE ROLE OF PERCEPTION IN REGULATING STRIDE-TO-STRIDE WALKING DYNAMICS

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1. Motivation

The Dynamic Walking community has rightly focused on the aspects of gait that can be modeled, predicted, and explained by the mechanics of multibody systems. Sensory feedback is assumed to play a role in walking, but generally via machine-like, relatively low-dimensional feedback control mechanisms in a virtually noise-free system. Human beings, however, are "perception-action" systems that perceive sensory inputs and organize motor responses in a variety of different ways, all while coping with fluctuations that are intrinsic to the decidedly high-dimensional human motor system. This suggests the need for a better understanding of the perceptual context in which locomotion occurs in order to fully understand how humans select and implement different control strategies to regulate walking.

2. State of the Art

Current approaches focus primarily on what are effectively the *mean* patterns of *within*-stride walking dynamics [1] (i.e., the mechanisms by which a single stride is generated), and assess the local orbital stability of the resulting limit cycles in a deterministic setting. But neuromotor variability is intrinsic, and perhaps even necessary, to human movement [2], and therefore critical to understanding motor control [3,4]. Here, we compare/contrast results from several different studies that analyzed stride-to-stride fluctuation dynamics in different perceptual contexts [5-9].

3. Our Approach

We treat stride length (L_n), stride time (T_n), and stride speed ($S_n = L_n/T_n$) as the fundamental gait observables that ultimately need to be regulated [1,5]. We construct *goal functions* [4,5] that are testable hypotheses on how fluctuations in these observables are regulated [5]. Detrended fluctuation analysis (DFA) [5,6] is one tool used for this purpose. The DFA exponent α has values > 0.5 for a statistically persistent time series, which we interpret as indicating weak control of fluctuations, whereas values of $\alpha \leq 0.5$ correspond to uncorrelated or anti-persistent fluctuations, indicating more rapid *corrections* of inter-stride deviations, therefore suggesting greater *control* [5,6].

4. Current Results

Overground walking elicits strong statistical persistence in L_n, T_n, and S_n [7]. However, when subjects walk overground in time with a metronome, only T_n becomes anti-persistent [7]. Similarly, on motorized treadmills, people highly regulate walking speed [5,6,8] fluctuations, whereas when treadmill walking *with* a metronome L_n, T_n, and S_n *all* become anti-persistent [8], as we would predict. Conversely, for treadmill walking in a virtual environment with visual optic flow [9], S_n returns to being persistent, similar to overground walking (see Fig. 1).

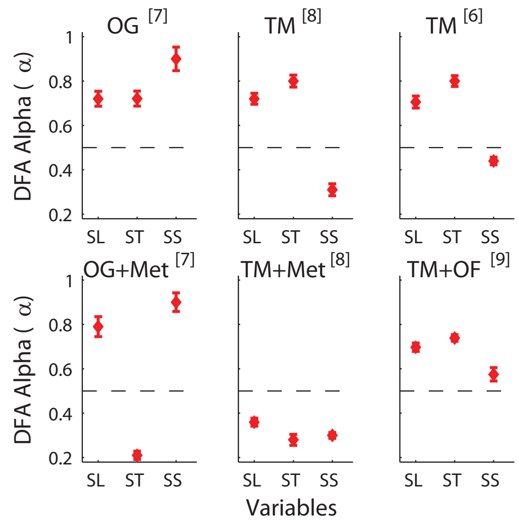

Fig. 1: DFA exponent α for stride observables from various studies ([#] indicates citation) under various conditions. OG: Overground; TM: Treadmill; Met: Metronome; OF Optic Flow.

5. Best Possible Outcome

These results clearly demonstrate that changes in visual, auditory, and/or other perceptual inputs strongly influence how humans regulate walking dynamics. A better understanding of the role of perception in this process will contribute to a coherent picture of how the complex, "noisy" neuromotor system couples to, and controls, the relatively low-dimensional mechanical dynamics of walking.

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