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Information for step length adjustment in running

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Abstract

The purpose of this study was to directly test the hypothesis that the tau parameter, as introduced by Lee et al. [Lee, D. N., Lishman, J. R., & Thomson, J. A. (1982). Regulation of gait in long jumping. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 448–459] and Warren et al. [Warren, W. H., Young, D. S., & Lee, D. N. (1986). Visual control of step length during running over irregular terrain. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 259–266], is the primary information used to regulate step length in running toward a ground target. Visual information available to research participants performing a facsimile of a long jump approach run was manipulated, and the effects on task performance and running gait were observed. Task performance and running gait were unaffected or minimally affected by (a) a perturbation of the normal optical expansion of the target, (b) elimination of global optical flow – including the focus of expansion, and (c) elimination or severe degradation of visual information about distance from the target as well as running velocity. The findings are inconsistent with notions that time-to-arrival with a ground target while running is predominantly specified optically by (a) local tau, (b) global tau, or (c) a distance/velocity computational strategy. A multisensory tau hypothesis regarding informational support for step length adjustment in running is offered.

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1. Introduction

In 1982, Lee, Lishman, and Thomson published an influential paper on the visual regulation of running gait in long jumping. The long jump approach run is performed at near maximum running velocity and requires precise adjustment of step length so that foot placement at jump takeoff is as close as possible to the distal edge of the 20-cm board from which the jump is measured. Based on analyses of foot placement throughout the run-up to the takeoff board, Lee et al. concluded that the long jump approach run consisted of an apparently stereotyped phase followed by a zeroing-in phase where vision is used to regulate step length. Subsequent studies of expert, novice and even non-long jumpers revealed that step length adjustment toward the end of the approach run for the purpose of enhancing takeoff accuracy is a ubiquitous feature of task performance (Berg, Wade, & Greer, 1994; Hay, 1988; Scott, Li, & Davids, 1997), although Montagne, Cornus, Glize, Quaine, and Laurent (2000) have shown that these data are also consistent with a mechanism for step length adjustment that operates continuously throughout the approach run.

Lee et al. (1982) also contemplated the type of visual information long jumpers used to modify step length to enhance accuracy. In analyzing the kinematics of several gait parameters over the later steps of the approach run, they found that long jumpers modified step time exclusively (i.e., the vertical impulse of step takeoff) in order to adjust step length, whereas horizontal velocity (i.e., the horizontal impulse of step takeoff) remained constant. Modulation of vertical impulse is the fundamental way in which humans control step duration in running, yet as Lee et al. observed, step length could be adjusted indirectly by modulating vertical impulse. Because long jumpers opted to regulate step length indirectly by modifying step time, Lee et al. concluded that adjustment in step length over the final steps of the long jump approach must be based on information about the time remaining before arrival at the takeoff board (*time-to-arrival*: TTA). Lee et al. posited that long jumpers perceive TTA and choose the durations of the remaining steps so as to fit the TTA, and in doing so produce step lengths appropriate for the distance remaining to the takeoff board. In other words, step length adjustment at the end of the long jump approach was thought to occur as a result of coupling information about TTA with a single method of regulating step length – adjustment of vertical impulse. Lee et al. also concluded that for long jumpers TTA is "specified directly by a single optical parameter, the inverse of the rate of dilation of the image of the board" (p. 456). The idea was that the visual system picks up TTA information from the expansion of the takeoff board and directs the locomotor system to make appropriate step length/time modifications for the steps remaining until arrival at the board (Magill, 2001). In subsequent papers (e.g., Lee, 1990; Warren, Young, & Lee, 1986), Lee and colleagues