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Perceptual-motor regulation in locomotor pointing while approaching a curb

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ABSTRACT

Locomotor pointing is a task that has been the focus of research in the context of sport (e.g. long jumping and cricket) as well as normal walking. Collectively, these studies have produced a broad understanding of locomotor pointing, but generalizability has been limited to laboratory type tasks and/or tasks with high spatial demands. The current study aimed to generalize previous findings in locomotor pointing to the common daily task of approaching and stepping on to a curb.

Sixteen people completed 33 repetitions of a task that required them to walk up to and step onto a curb. Information about their foot placement was collected using a combination of measures derived from a pressure-sensitive walkway and video data. Variables related to perceptual-motor regulation were analyzed on an inter-trial, intra-step and inter-step level.

Similar to previous studies, analysis of the foot placements showed that, variability in foot placement decreased as the participants drew closer to the curb. Regulation seemed to be initiated earlier in this study compared to previous studies, as shown by a decreasing variability in foot placement as early as eight steps before reaching the curb. Furthermore, it was shown that when walking up to the curb, most people regulated their walk in a way so as to achieve minimal variability in the foot placement on top of the curb, rather than a placement in front of the curb. Combined, these results showed a strong perceptual-motor coupling in the task of approaching and stepping up a curb, rendering this task a suitable test for perceptual-motor regulation in walking.

1. Introduction

Placing one's foot onto a target on the ground during gait, otherwise known as 'locomotor pointing', is important in athletic contexts (e.g. the run up for a long jump) as well as everyday walking. Appropriate locomotor pointing in sport is often critical (e.g. every centimeter of error in the long jump run-up is a centimeter lost in the jump) and this has led to extensive study in the sporting context [1–10] and research on perceptual-motor regulation strategies in locomotor pointing [2,11,12]. With the aim to devise a suitable task for perceptual-motor regulation in walking, the current study investigated whether these results generalize to the everyday task of approaching and stepping up on to a curb.

Early studies on locomotor pointing were performed in the run up for a long jump [1–8]. In this event, it is important for an athlete to regulate their running gait in such a way so as to ensure that they end their run-up with their take-off foot as close to the edge of the take-off board as possible. It was shown that this low error is achieved through visual regulation [1,2]. In the initial stage of the run up, foot placements are more variable, but become more consistent later in the performance when the athlete enters a regulation phase to ensure that they end with minimal error between the positioning of their foot and the edge of the take-off board.

Two previous studies of locomotor pointing have sought to determine when visual regulation was *initiated*, by examining locomotor pointing on a trial-by-trial basis. One study focused on the long jump run up [2] and the other study focused on a walking task that involved participants stepping over an obstacle [13]. Both these studies defined the onset of regulation as the moment that steps in the run-up or walk became different from the average step length recorded under steady-state conditions. Results indicated that the onset of regulation was not fixed, but rather, was related to the amount of adjustment required. They showed that if greater adjustment was required, the onset of regulation was earlier compared to runs or walks with lower required adjustment. Ultimately, these results indicated that the onset of regulation was dependent on continuous perception-movement coupling

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[2,13].

Locomotor pointing is a skill that is often executed in daily life and is important during tasks such as approaching a set of stairs or a curb. Despite this, research has mainly focused on tasks that are not commonplace in daily life, such as sporting tasks [1–10] as well as laboratory tasks such as stepping onto or over abstract targets. For some of these studies, the target has only appeared moments before the required step (e.g. [14]) or has been incorporated into specific laboratory equipment, such as treadmills [15] or virtual reality systems [12]. By incorporating a task that involves an every-day activity, the current study aimed to generalize the findings of previous locomotor pointing research [2,13] to everyday situations. Whilst the current study is still laboratory-based, the required action more closely approximates and, hence is more generalizable to every-day behaviors than any of the preceding studies.

The task used in the current study involved stepping onto a regulation-height − *curb-like* − two meter long platform. Stepping up onto such a curb-like platform is different from stepping on a target or avoiding obstacles in the sense that the spatial demands are lower as a curb does not dictate where and how to step up. A step up can be achieved via any place in front of the curb, to any place on top, as long as the demands of the step stay within a person's action capabilities. These lower accuracy demands allow a step up that would not require a large decrease in walking speed [16]. These demands are not as strict as, for instance, those of a long jump, in which locomotor speed requirements are high and each centimeter away from the take-off board means a centimeter shorter jump distance. Compare this to the approach to a curb in which a foot positioned too close to the curb will turn the curb into a tripping hazard and a position too far away will make the curb unreachable. Both of these scenarios have negative consequences for the efficiency of progression.

The current study aimed to investigate whether previous results in locomotor pointing regulation in a setting with higher spatial demands (the long jump approach [2], walking to specific targets [13]) can be generalized to approaching a curb. As age-related declines in cognition and action capabilities make it unethical to evaluate perceptual-motor regulation during high-speed movements, such as the long-jump approach, this study has the potential to provide new opportunities to study this process in an ageing population. However, before being able to use the curb-approaching task as a measurement tool for perceptual-motor regulation, the current study compared regulation in this task to the previous studies of locomotor pointing. Specifically, we aimed to assess whether, similarly to other studies of perceptual-motor regulation [2,13], a decrease in variability of step placement is shown when an individual approaches a curb-like platform and whether this regulation is dependent on the required adjustment (implying a continuous coupling between perception and action).

2. Method

2.1. Participants

Sixteen healthy participants (9 males, 7 females) volunteered to participate in the study (mean (SD) age: 25.5 (3.8) years). All participants were recruited from the university environment, had normal or corrected to normal vision and signed a consent form prior to their participation. The protocol of the study was approved by the institutional Human Research Ethics Committee.

2.2. Protocol and materials

Participants were instructed to walk 8.5-m along a pressure-sensitive walkway (GAITRite®, CIR Systems, Inc., Franklyn, NJ, USA), starting from a constant starting position at one end of the GAITRite mat and before stepping onto a purpose-built curb-like platform (dimensions LxWxH: 2.00 × 1.00 × 0.15 m) positioned at the other end of the walkway (creating a 10-m walk). A switch was fitted to a post (height 1.35 m) at the far end of the platform and participants were instructed to "walk up to the platform, step up and flick the switch at the far end" to signal the end of each trial. Prior to data collection, participants performed a minimum of three practice walks along the walkway and onto the platform to establish their preferred step length, which was used to set up the main experiment. If the experimenter judged one of the three practice walks to be inconsistent in terms of step length (for instance, some participants started their first walk more cautiously), the data from this trial was excluded and an extra walk was performed to ensure a representative average.

The aim of this experiment was to assess similarities between a long jump running approach [2,13] and a walking task, but the dimensions of our lab did not allow our participants enough space to complete a similar number of strides to that which would be used in a long jump approach. Given that research has shown that variability in foot placement accumulates during the initial phase of the long jumping approach [1], athletes are inevitably exposed to different task demands each time they enter a regulation phase and variability is minimized. Similarly, when approaching a curb in the real world environment, the conditions that an individual performs under, such as their starting position relative to the curb, are rarely identical over repeated performances. As such, the current study used the following manipulation to promote variability in the demands of each repeat performance and to better replicate the circumstances experienced in real life when entering the regulation phase. Participants were instructed to place one of their first steps on a target mat of anti-slip material (bright blue color, dimensions LxW: 0.30 × 1.50 m) that was positioned in one of 10 different positions in front of the participant's starting position at evenly spaced distances ranging from 1 to 2.5 times their preferred step length. Participants were asked to place their full foot on the anti-slip material, but were not limited with respect to the number of steps that they took to achieve this goal (i.e. some may have taken one step, while others would have taken two or three steps). Participants were asked to try and incorporate stepping on the target in their natural gait and to continue walking along the walkway as naturally as possible. The target mat at the start of the walkway was presented as a secondary goal; their primary goal was reaching the switch at the end of the walkway. If a participant was unsuccessful in placing the full foot on the target at the start of the walkway, the trial continued as normal, with the participant walking further towards the platform (no outcomes were derived from this procedure). An 11th condition was added in which no target was presented and the participant walked freely towards the platform. Conditions were repeated three times each and were presented in a random order, resulting in a total of 33 trials per participant.

Information about the participants' foot placements was automatically collected and digitized by the GAITRite system; the forefoot centroid computed by GAITRite was extracted and used to represent the foot position relative to the curb. This foot placement data was exported to Microsoft Excel. As the GAITRite system was incapable of measuring foot positions on top of the platform, information about foot placements immediately prior to and on the platform was also captured using a digital video camera (CASIO, EX-FH100) positioned 2.35 m from the edge of the platform, perpendicular to the direction of walking. Calibration of the video footage was completed using two reference markers placed 30 cm apart on the closest side of the platform. Videos were analyzed using Kinovea (version 0.8.15, ©2006-2011 Joan Charmant & Contrib.) by three research assistants, in order to extract the position of the forefoot from the participants on top of the platform. Videos from three participants (396 foot placements identified by each assessor; 3 participants * 33 walks * 2 footfalls * 2 coordinates: heel and toe measures) were rated by all three assistants. Inter-rater reliability was determined to be excellent (ICC = 0.99).

To validate the measures derived from the video camera, the footfall data for four participants were collected using a Vicon 3-dimensional motion analysis system (Vicon Motion Systems), with a marker

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