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Continuous cognitive task promotes greater postural stability than an internal or external focus of attention

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ABSTRACT

Research has demonstrated clear advantages of using an external focus of attention in postural control tasks, presumably since it allows a more automatic control of posture to emerge. However, the influence of cognitive tasks on postural stability has produced discordant results. This study aimed to compare the effects of an internal focus of attention, an external focus of attention and a continuous cognitive task on postural control. Twenty healthy participants (21.4 ± 2.6 years) were recruited for this study. They were asked to stand quietly on a force platform with their feet together in three different attentional focus conditions: an internal focus condition (minimizing movements of the hips), an external focus condition (minimizing movements of markers placed on the hips) and a cognitive task condition (silently counting the total number of times a single digit was verbalized in a 3-digit sequence comprised of 30 numbers). Results demonstrated improved stability while performing the cognitive task as opposed to the internal and external focus conditions, as evidenced by a reduction in sway area, sway variability in the anterior–posterior (AP) and medial–lateral (ML) directions, and mean velocity (ML only). Results suggest that the use of a continuous cognitive task permits attention to be withdrawn from the postural task, thereby facilitating a more automatic control of posture.

1. Introduction

Instructions that direct attention to the effects of a movement on an apparatus or instrument (external focus) have repeatedly been shown to enhance learning and performance of motor skills compared to directing attention to the production of a movement (internal focus) [1–3, see 4 for review]. Recent empirical evidence suggests that concentrating on the effects of postural sway (external focus) is also advantageous for postural performance as opposed to concentrating on postural sway (internal focus) [3,5,6]. Wulf et al. [2] examined if the differential effects of an external versus an internal focus of attention could be replicated when balancing on a stabilometer platform. Participants were instructed to focus on either keeping their feet horizontal (internal focus) or keeping the red markers on the stabilometer horizontal (external focus). Results demonstrated improved balance performance in retention with an external focus compared to an internal focus.

According to the constrained action hypothesis, consciously controlling one's movement interferes in the coordination of automatic processes responsible for regulating the movement [1,3]. Conversely, diverting attention to the effects of a movement enables the automatic processes to operate unconstrained, thereby generating movement more efficiently [1,3]. Interestingly, the effectiveness of an external focus of attention has been shown to vary as a function of the distance between the action and its remote effect [1]. McNevin et al. [1] manipulated the distance of the external effect by instructing participants balancing on a stabilometer to focus on markers located at different distances from their feet. The results clearly demonstrated that increasing the distance of the effect (movement of the marker) from the action (postural sway) that produced it enhanced participants' ability to maintain balance on the stabilometer.

On the other hand, due to contradictory results, the nature of the relationship between postural control and cognition remains poorly defined. Studies on young adults have reported increased [7–9], unperturbed [10] and decreased [11–14] postural sway during the execution of concurrent cognitive tasks. For instance, Pellecchia [7] observed diminished postural stability while standing on a compliant surface and concurrently performing an information reduction task. Conversely, Stins et al. [14] found reduced COP amplitude and increased sway frequencies under a

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dual-task condition. Likewise, Andersson et al. [12] observed less postural sway when participants were instructed to count backwards in steps of seven.

The absence of consistent empirical evidence is postulated to be a result of one of several factors such as the processing demands of the cognitive task [7,13,15–17], the difficulty of the postural task [9,18,19] and the utilization of a stiffening strategy [5,14]. Postural stability is suggested to either improve or attenuate depending on whether the cognitive demand of the secondary task is lower or higher, respectively [16,17]. However, increasing the complexity of the cognitive task has resulted in the same contradictory results. Some studies have indicated an increase in postural sway while executing a difficult cognitive task [7,13], whereas others have observed a decrease in postural sway [15,16]. Moreover, changes in the postural parameters that accompany the performance of a cognitive task may be partly due to the nature of the task, specifically if it is discrete or continuous. For example, the inter-stimulus intervals in a reaction time (RT) trial may provide brief opportunities for participants to engage in conscious control. On the other hand, a continuous task, that requires attention for the complete duration of a trial, may limit opportunities for cognitive involvement in the postural control process; however, this assumption requires further exploration.

Recently, center of pressure (COP) measures reflecting the dynamical structure of COP fluctuations have been used to elucidate the complexity of the postural control system [21]. Donker et al. [21] found that performing a cognitive task when standing with eyes closed led to greater COP irregularity, while increasing conscious involvement in postural control by altering the task difficulty resulted in increased COP regularity. These findings, specifically the increase in irregularity, were interpreted to suggest that experimentally withdrawing attention enhances the efficiency or "automaticity" of the postural control system. Additionally, the frequency of adjustments has been found to increase as the focus of attention shifts farther from the body [3]. For that reason, a high mean power frequency (MPF) has been interpreted to suggest the use of more automatic control processes.

Therefore, the aim of the present study was to identify whether diverting attention away from postural control using a continuous cognitive task could produce greater postural stability than an internal and external focus of attention. The first proposed hypothesis was that the cognitive task would improve postural control compared to the internal and external focus conditions by generating a smaller sway area, decreased sway variability in the anterior–posterior (AP) and medial–lateral (ML) directions and reduced mean velocity in the AP and ML directions. The second hypothesis was that the external focus would improve postural control relative to the internal focus as evidenced by a smaller sway area, decreased sway variability (AP and ML) and reduced mean velocity (AP and ML). Finally, it was hypothesized that the cognitive task would promote greater automatic control processes compared to internal and external focus as evidenced by an increase in the frequency of adjustments.

2. Methods

2.1. Participants

Twenty young adults (10 males, 10 females; 21.4 ± 2.6 years) were recruited from the University of Ottawa to participate in the current study. A health questionnaire was used to ensure participants had no injury or condition that could impact their balance. Each participant gave written consent before taking part in the study. None of the participants had prior experience with the task. The protocol was approved by the Research Ethics Board at the University of Ottawa in accordance with the principles of the Declaration of Helsinki.

2.2. Apparatus

To evaluate postural control, an AMTI force platform (ORG-6-1000, Don Mills, ON, Canada) was used to collect the body's projection of ground-reaction forces at a sampling frequency of 500 Hz. A digital media player was used to present the audio recordings for the cognitive task.

2.3. Procedure

The experimental protocol consisted of three attentional focus conditions (internal, external and cognitive). Each condition was comprised of two equivalent blocks of five 60-s trials. The blocks were counterbalanced across participants. Instructions pertaining to the postural task were identical across all experimental conditions. Participants were asked to stand as still as possible on the force platform with their feet together, arms by their sides, while fixating on an eye-level target 3 meters from the force platform. Instructions concerning attentional focus were specific to condition. For the internal focus condition, participants were instructed to concentrate on minimizing the movement of their hips as much as possible. For the external focus condition, participants were instructed to concentrate on minimizing the movement of the markers placed on their hips as much as possible. The markers were placed using an elastic belt with two markers on the ventral side (i.e. anterior superior iliac spine) and two markers on the dorsal side (i.e. posterior superior iliac spine). The belt was removed when participants were not engaging in an external focus of attention. Manipulation checks were performed after every internal and external focus trial to ensure attention was allocated to the instructed task. Participants were asked to provide a subjective percentage rating (0–100%) indicating how engaged they were in the instructed attentional focus. If a value of 50% or lower was provided the trial was redone. Across all participants, a total of four trials were redone (three internal and one external). For the cognitive task condition, participants were instructed to silently count the total number of times a pre-selected digit (e.g. 0–9) was verbalized via an audio recording in a 3-digit sequence. The sequence was comprised of 30 numbers with a new number presented every 2 s. The task was continuous in the sense that it was performed for the full duration of the trial with no delays or articulation. The task required participants to not only count the occurrence of the selected digit but to simultaneously add it to their running total. Using fingers as a counting aid was prohibited. Participants provided their total count to the investigator upon completion of the trial. For each consecutive cognitive trial, participants were presented with a new digit to count. The policy was to redo a trial if the participant's answer was off by three or more. Nineteen participants committed errors, however, no trials were discarded. Two different sequences were used interchangeably to reduce participants' chances of memorizing the order. The cognitive task was performed silently to eliminate the potential influence of articulation on postural sway [20]. The digital media player was placed directly behind the participant.

2.4. Data analyses

The COP was obtained using the ground-reaction forces collected by the force platform. MatLab software (MathWorks Inc., MA, USA) was used to derive several outcome measures such as area of 95% confidence ellipse, standard deviation (SD) of COP in the AP and ML direction, and mean velocity in the AP and ML direction to characterize postural control. In addition, a Fast