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Reducing postural sway by concurrently performing challenging cognitive tasks

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ABSTRACT

The present experiment varied cognitive complexity and sensory modality on postural control in young adults. Seventeen participants (23.71 ± 1.99 years) were instructed to stand feet together on a force platform while concurrently performing cognitive tasks of varying degrees of difficulty (easy, moderate and difficult). The cognitive tasks were presented both, auditorily and visually. Auditory tasks consisted of counting the occurrence of one or two letters and repeating a string of words. Visual tasks consisted of counting the occurrence of one or two numbers. With increasing cognitive demand, area of 95% confidence ellipse and ML sway variability was significantly reduced. The visual tasks reduced ML sway variability, whereas the auditory tasks increased COP irregularity. We suggest that these findings are primarily due to an increase in sensorimotor integration as a result of a shift in attentional focus.

1. Introduction

Since the automaticity of postural control has been brought into question (Kerr, Condon, & McDonald, 1985), a considerable amount of research using dual-task paradigms (i.e., comparing the performance of two tasks executed simultaneously) has been done to better understand the interaction between cognition and postural control (Woollacott & Shumway-Cook, 2002). The underlying assumption of a dual-task paradigm is that if two concurrent tasks exceed total resource capacity, performance on one or both tasks will fall below baseline (Kahneman, 1973; Woollacott & Shumway-Cook, 2002). However, the reported cases of reduced postural sway highlight a significant limitation to the assumption, specifically its inability to account for greater postural stability (Huxhold, Li, Schmiedek, & Lindenberger, 2006; Riley, Baker, & Schmit, 2003; Swan, Otani, & Loubert, 2007).

Moreover, discerning a clear pattern to the current literature is rather challenging on account of the large variability in experimental protocols, cognitive tasks, posturographic measures (Mitra & Fraizer, 2004) and as pointed out by Stins and Beek (2012), the lack of consensus as to what characterizes postural instability. With a relatively simple postural task (e.g., unperturbed stance), performing a concurrent cognitive task has been found to elicit both, an increase (Pellecchia, 2003; Woollacott & Vander Velde, 2008) and decrease (Huxhold et al., 2006; Kerr et al., 1985; Riley et al., 2003; Swan et al., 2007) in postural sway. An increase in postural sway as evidenced by posturographic measures such as large sway area, high center of pressure (COP) variability and/or large COP path length, is commonly associated with postural instability (Stins & Beek, 2012). However, it is possible that both tasks are integrated according to the task's respective resource

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demands (Stoffregen, Hove, Bardy, Riley, & Bonnet, 2007). Stoffregen, Smart, Bardy, and Pagulayan (1999) proposed that postural control could be regulated to facilitate the performance of a secondary task (i.e., cognitive task). Applying this a priori argument, it is possible that cognitive tasks such as Brooks' spatial and non-spatial memory tasks, counting backwards and n-back tasks require different degrees of postural stabilization, which could explain why variability in postural sway is observed (Kerr et al., 1985; Maylor, Allison, & Wing, 2001; Pellecchia, 2003; Stoffregen et al., 2007, 1999; Woollacott & Vander Velde, 2008).

Alternatively, we propose that in cases with minimal postural demand (e.g., unperturbed stance, large base of support, etc.), the reported fluctuations in postural sway may be attributed to attentional interference precipitated by the cognitive task than a potential competition for processing resources. The allocation of an individual's focus of attention has been shown to impact the performance of motor skills such as postural control (Shea & Wulf, 1999; Wulf, Hob, & Prinz, 1998; Wulf, McNevin, & Shea, 2001; for a review, see Wulf, 2007). Directing attention towards the movement itself (i.e., internal focus) is suggested to interfere with the coordination of motor control processes responsible for regulating the movement, causing awkward movement patterns (McNevin, Shea, & Wulf, 2003). Whereas, directing attention towards the effect of a movement on an apparatus or implement (i.e., external focus) is suggested to minimize interference with the control processes and promote a more automatic mode of movement control. In addition, placing attentional focus on a more distal point has been shown to yield an increase in mean power frequency (MPF) (McNevin et al., 2003; Wulf, McNevin, et al., 2001; Wulf, Shea, & Park, 2001). A higher frequency of responding is suggested to reflect superior sensorimotor integration as a result of an increase in active degrees of freedom and greater coherence between reflexive and voluntary movement (McNevin et al., 2003; Wulf, McNevin, et al., 2001). Conversely, an internal focus is thought to impose constraints on the degrees of freedom and control mechanisms, ultimately disrupting movement execution (McNevin et al., 2003; Wulf, McNevin, et al., 2001). Therefore, based on the requirements of the cognitive task, attentional focus may deviate to a movement of the body, or a point proximal to the body thereby, interfering with the control processes of postural stability (McNevin et al., 2003).

To achieve a greater understanding of the underlying motor control processes, evaluating the magnitude of postural sway needs to involve the use of dynamic measures (e.g., sample entropy, recurrence quantification analysis, etc.), alongside the commonly used spatial measures (e.g., area of 95% confidence ellipse, COP variability, COP velocity, path length, etc.) (Roerdink et al., 2006). Sample entropy is a dynamic measure that indexes the statistical regularity of COP fluctuations (Stins, Michielsen, Roerdink, & Beek, 2009; Stins, Roerdink, & Beek, 2011). Low values signify greater COP regularity and high values signify less COP regularity. Roerdink et al. (2006) were the first to compute sample entropy using COP data. They found high medial–lateral (ML) COP regularity in stroke patients during quiet standing and a decrease in COP regularity during the course of rehabilitation. Roerdink et al. (2006) suggest that increased COP regularity reflects a higher degree of attentional investment in postural control, whereas increased COP irregularity reflects a reduction in attentional investment, representative of a more automatic mode of movement control.

In the posture-cognition literature, it is common practice to assume that the cognitive tasks within a given study are of equal demand, although evidence is rarely provided to support such an inference (Stoffregen et al., 2007). Therefore, differences observed between working memory tasks (Maylor & Wing, 1996) or tasks with spatial or non-spatial components (Maylor et al., 2001; Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997) may be influenced by the task's cognitive demands and not merely the use of different processing areas of the brain (Stoffregen et al., 2007). Numerous studies have manipulated cognitive demand (Huxhold et al., 2006; Pellecchia, 2003; Swan et al., 2007) but very few have has used any independent measure to verify (Stoffregen et al., 2007). To address this issue, we assessed each task prior to testing to ensure they varied in difficulty and any differences observed between tasks could be attributed to cognitive demand.

Similarly, the influence of sensory modality on postural control has been examined on several occasions with findings being inconclusive (Jamet, Deviterne, Gauchard, Vancon, & Perrin, 2007; Riley, Baker, Schmit, & Weaver, 2005). However, the use of both, spatial and dynamic measures has to our knowledge only been done by one study by Riley et al. (2005). Both, the auditory and visual short-term memory tasks reduced ML sway variability with increasing cognitive load, however, the auditory task was correlated with greater changes to the spatiotemporal profile of postural control (e.g., decrease in anterior-posterior (AP) and ML % recurrence and % determinism). Conversely, we suspect that relative to auditory tasks, visual tasks would yield less postural sway by serving as visual anchors (Vander Velde, Woollacott, & Shumway-Cook, 2005). Therefore, testing this hypothesis was part of the motivation for conducting the present experiment.

The objective of the present experiment was to investigate cognitive demand and sensory modality on postural control using both, spatial and dynamic measures. Firstly, we hypothesized that performing the difficult level cognitive task would lead to a reduction in postural sway as evidenced by a reduction in area of 95% confidence ellipse and sway variability and an increase in COP irregularity. Secondly, as opposed to Riley et al. (2005), we hypothesized that presenting the tasks visually would lead to a reduction in postural sway as evidenced by a smaller area of 95% confidence ellipse and sway variability and an increase in COP irregularity.

2. Methods

2.1. Participants

Seventeen healthy University of Ottawa students (Nine females, eight males; 23.71 ± 1.99 years) participated in the experimental protocol. A health questionnaire was administered to ensure participants had no injuries or disorders that