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RESEARCH ARTICLE

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Attentional demands associated with the use of a light fingertip touch for postural control during quiet standing

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Abstract The purpose of the present experiment was to investigate whether and how using a light fingertip touch for postural control during quiet standing requires additional attentional demands. Nine young healthy university students were asked to respond as rapidly as possible to an unpredictable auditory stimulus while maintaining stable seated and upright postures in three sensory conditions: vision, no-vision and no-vision/touch. Touch condition involved a gentle light touch with the right index finger on a nearby surface at waist height. Center of foot pressure (CoP) displacements were recorded using a force platform. Reaction times (RTs) values were used as an index of the attentional demand necessary for calibrating the postural system. Results showed decreased CoP displacements in both the vision and no-vision/touch conditions relative to the no-vision condition. More interestingly, a longer RT in the no-vision/touch than in the vision and no-vision conditions was observed. The present findings suggest that the ability to use a light fingertip touch as a source of sensory information to improve postural control during quiet standing is attention demanding.

Keywords Light fingertip touch · Attentional demand · Postural control · Human

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Introduction

Postural control is a particularly complex system that involves various sensory and motor components. While for decades visual input has been demonstrated to play a dominant role in postural control (e.g., Lee and Lishman 1975), haptic cues from the finger have recently become of increased interest. During quiet stance, a light (i.e., non-supportive) fingertip touch has been shown to reduce postural sway, even though the contact forces were far below from those necessary to provide a mechanical support (e.g., Clapp and Wing 1999; Dickstein et al. 2001; Holden et al. 1994; Jeka 1997; Jeka and Lackner 1994, 1995; Lackner et al. 2001; Riley et al. 1997, 1999; Vuillerme and Nougier, 2003). These results suggest that haptic cues from the fingertip can be integrated with other sensory information by the central nervous system to provide additional spatial orientation for postural stabilization during quiet standing. In addition, evidence that postural control requires attentional resources has been also provided by numerous studies using dual-task paradigms (see Woollacott and Shumway-Cook 2002, for a review). In general, results showed that even tasks considered as automated and/or involving lower order operations require some attentional resources. Further, a common observation of these studies is that the attentional demand associated with postural control can be modified by the sensory context. Decreasing (Teasdale et al. 1993), conflicting (Redfern et al. 2001), or reintegrating (Teasdale and Simoneau 2001) sensory information has been shown to require increased attentional resources for regulating postural sway during quiet standing. As recently mentioned by Bateni and Maki (2005), it is surprising that there is an absence of data showing whether and how the attentional demand associated with postural control is modified with the use of fingertip touch.

The purpose of the present experiment was thus to investigate whether and how using a light fingertip touch for postural control during quiet standing requires additional attentional demands, using a dual-task paradigm. It was hypothesized that (1) the availability of a light fingertip touch decreases postural sway and (2) the ability to use a light fingertip touch as a source of sensory information for controlling balance during quiet standing is attention demanding.

Methods

Subjects

Nine young male right-handed university students (mean age: 23.7 ± 1.9 years; range: 21–27 years) participated in the experiment. They were naïve as to the purpose of the study. They gave their written informed consent to the experimental procedure as required by the Helsinki declaration and the local Ethics Committee. None of the subjects presented any history of motor problem, neurological disease or vestibular impairment.

Task and procedure

Subjects stood barefoot on a force platform, feet together. The force platform (AMTI model OR6-5-1) was used to measure displacements of the center of foot pressure (CoP). Signals from the force platform were sampled at 100 Hz (12 bit A/D conversion) and filtered with a second-order Butterworth filter (10 Hz low-pass cut-off frequency with dual pass to remove phase shift). Subjects' task was to sway as little as possible in three conditions of vision, no-vision and no-vision/touch. In the vision condition, they were asked to fixate a white cross (20×25 cm) located 1.20 m away from the force platform, at the eyes level. In the no-vision and no-vision/touch conditions, they were asked to close their eyes and to keep their gaze in a straight-ahead direction. In the no-vision/touch condition, subjects extended their right arm to touch a cloth curtain suspended from the ceiling with the tip of the index finger at waist height. This non-rigid surface used for the fingertip contact could not provide a mechanical support for stance and was similar to the one employed by Riley et al. (1999) and Vuillerme and Nougier (2003). Subjects were instructed to keep the forearm parallel to the ground and to maintain a light contact with the curtain. They were asked to let the left arm hang naturally by the side. In the no-vision and vision conditions, the curtain was moved out of subjects' reach, and subjects were instructed to hold the right arm out in the same position they had in the no-vision/touch condition.

While performing the postural task, subjects also performed a probe-reaction time (RT) task. The RT task consisted of responding as rapidly as possible to an unpredictable auditory stimulus (100 ms, 1,000 Hz) by pressing a handheld button with the left thumb (500 Hz sampling frequency). This technique is central to several information-processing models proposing that the central nervous system has a limited capacity. It is assumed that performing a task requires a given portion of this capacity, and that if two tasks performed simultaneously require more than the total capacity, the performance of one or both tasks will be affected negatively (e.g., Kahneman 1973). In the present experiment, subjects were asked to consider the postural task as the primary task, whereas the RT task was the secondary task. Within this so-called dual-task paradigm, any change in RT presumably would reflect changes in the resources necessary for performing the postural task. For each trial (20 s), a maximum of 5 randomly presented auditory stimuli separated by at least 2 s could be presented. The number and timing of the stimuli delivered were similar for each experimental condition. Five trials for each experimental condition were performed, the order of presentation of these experimental conditions being randomized over subjects. Subjects also were submitted to a control condition in which their RT to an auditory stimulus was evaluated in a seated position. No postural measures were taken as this task only served to establish a baseline RT value for each subject. However, a primary threat to the validity of the dual-task paradigm is attention switching or performance tradeoff on the primary task to increase performance in the secondary task. To ensure that subjects did not neglect postural control in favor of attending to the auditory stimulus, the three upright postural conditions were also performed alone without executing the RT task (five "baseline" trials for each upright posture).

Analyses

Center of foot pressure path length (in centimeters) was used to quantify postural sway in the three upright postures. This measure corresponds to the sum of the displacement scalars over the 20 s sampling period. RT (in milliseconds) served to estimate the attentional demand necessary for performing the postural task. RT was defined as the temporal interval between the presentation of the auditory stimulus and the subjects' response (pressing the button). The mean CoP path length and RT for each subject during each experimental condition were calculated. Repeated-measures analyses of variance (ANOVAs) were used for statistical comparison of the different conditions. Level of significance was set at 0.05. Post-hoc analyses (Newman-Keuls) were used when a significant main effect of Sensory condition or Posture was observed.

Results

CoP displacements

A two-way repeated-measures ANOVA 2 Tasks conditions (RT vs. No-RT task) ×3 sensory conditions (vision vs. no-vision vs. no-vision/touch) was applied to the

CoP data. Results showed a main effect of sensory condition ($F(2,16) = 19.77$, $P < 0.001$), with smaller CoP path length in the vision than in the no-vision condition ($P < 0.001$) and smaller CoP path length in the no-vision/touch than in the no-vision condition ($P < 0.001$) (Fig. 1). Furthermore, the absence of an interaction of task × sensory condition ($F(2,16) = 0.25$, $P < 0.781$) and of an effect of task ($F(1,8) = 2.42$, $P < 0.159$) showed that the addition of the secondary task (RT task) did not affect the performance in the primary task (postural control). This suggests that subjects did not switch attention from the primary to the secondary task during the dual-task conditions and therefore validates the RT data as a valid index of the attentional demand required by the postural task.

Attentional demand

In order to examine the attentional demand associated with the postural task, a one-way repeated-measures ANOVA 4 postures (seated vs. vision vs. no-vision vs. no-vision/touch) was applied to the RT data. Results showed a main effect of posture ($F(3,24) = 16.23$, $P < 0.001$), yielding a shorter RT in the Seated than in the three upright conditions, i.e. vision ($P < 0.003$), no-vision ($P < 0.001$) and no-vision/touch ($P < 0.001$) and a longer RT in the no-vision/touch than in the vision ($P < 0.007$) and no-vision conditions ($P < 0.032$) (Fig. 2).

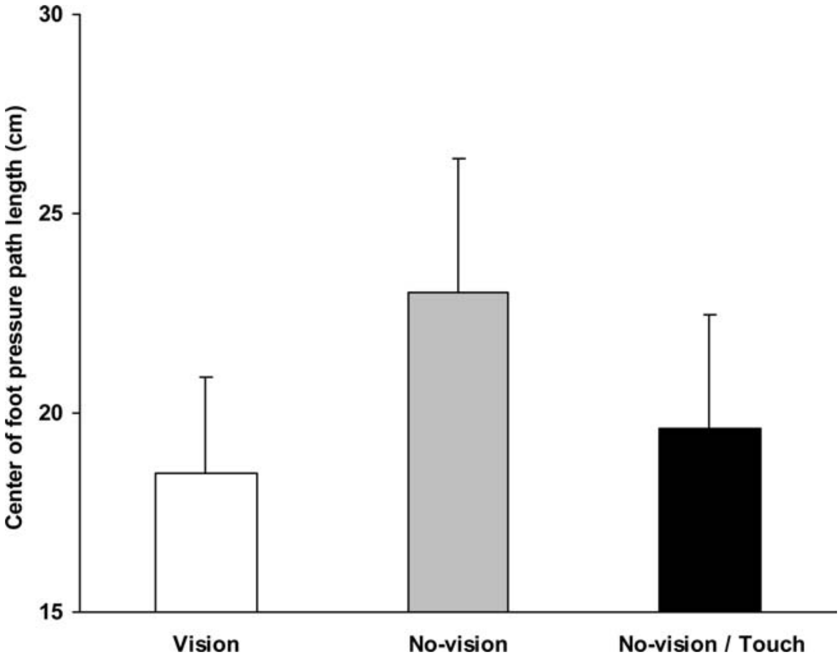
Discussion

The purpose of the present experiment was to investigate whether and how using a light fingertip touch for postural control during quiet standing requires additional attentional demands, using a dual-task paradigm.

Regarding the postural data, results showed decreased CoP path length in both the Vision and No-vision/Touch conditions relative to the No-vision condition (Fig. 1), hence confirming our first hypothesis. These findings agree with those of previous studies demonstrating that light touch has a comparable effect to that of vision in decreasing CoP displacements during quiet standing (e.g., Clapp and Wing 1999; Holden et al. 1994; Jeka 1997; Jeka and Lackner 1994, 1995; Riley et al. 1997).

Regarding the RT data, by showing longer RTs in upright than in the seated condition, our results first confirmed that postural control is not fully automatic but still requires a portion of the attentional resources available (e.g., Lajoie et al. 1993, 1996; Teasdale et al. 1993; Teasdale and Simoneau 2001; Vuillerme and Nougier 2004). More interestingly, the no-vision/touch condition yielded an increased RT as compared to the no-vision condition. These results suggested that, contrary to visual information, the integration of a light fingertip touch information for controlling posture requires an additional attentional demand (Fig. 2), hence confirming our second hypothesis. With regard to the hypothesis of an integration of somaesthetic information in the no-vision/touch condition, our results are in line with those of Teasdale and Simoneau (2001). When ankle proprioceptive information had to be reintegrated in the absence of vision, an increased attentional demand for maintaining a stable standing posture was reported in young healthy adults. Interestingly, this observation was associated with a concomitant increased postural sway. In addition, these effects were immediate and transient and since RT values and CoP

Fig. 1 Mean CoP path length and standard deviation (cm) obtained in the three sensory conditions (vision, no-vision and no-vision/touch). These experimental conditions are presented with *different symbols*: Vision (*white bars*), no-vision (*grey bars*) and no-vision/touch (*black bars*). (Note that the *y*-axis scale has been magnified)



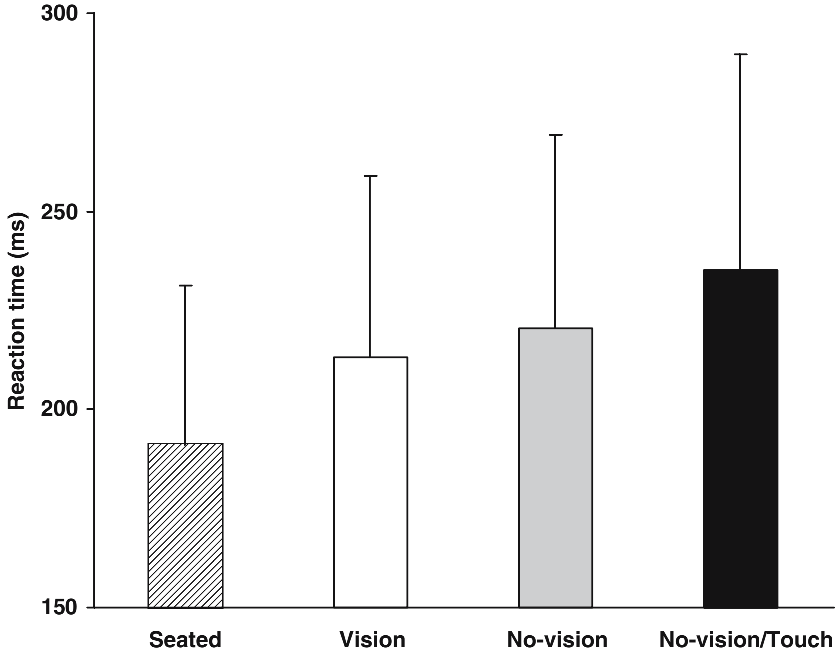


Fig. 2 Mean RT and standard deviation (ms) obtained for the seated and the three upright postures in the three sensory conditions (vision, no-vision and no-vision/touch). These experimental conditions are presented with different symbols: seated (*hatched bars*), vision (*white bars*), no-vision (*grey bars*) and no-vision/touch (*black bars*). (Note that the *y*-axis scale has been magnified)

displacements decreased and returned to their baseline level within a period of 10 s (Teasdale and Simoneau 2001). This was not the case in the present experiment, the integration of a light finger tip touch for postural control during quiet standing yielding an increased attentional demand (Fig. 2) and decreased CoP displacements (Fig. 1). Although the postural task was different, our results are also in line with those of Wright and Kemp (1992), showing that healthy subjects using walking aids require higher cognitive processing than they do during normal walking. In this study, however, the experimental protocol involved much more than the integration of sensory information (light finger touch), i.e. there was also a motor component (moving the walking) that may have resulted in increased attentional demands *per se*. Finally, it is important to mention that, during daily life activity, proprioceptive information used to stabilize a bipedal standing posture mainly comes from the lower-limbs. The cloth curtain could be viewed as the introduction of a new spatial referent, allowing exploiting a new set of (proprioceptive) spatiotemporal relationships for regulating posture. It is thus possible that the longer RTs observed in the no-vision/touch condition could stem from the use of an unusual source of information for postural control or from the novelty of the postural situation. Along these lines, recent studies have provided evidences that the level of automaticity of postural control could be significantly increased through repetition (Wulf et al. 2001) or specific and/or extensive postural training (Lajoie 2004; Vuillerme and Nougier 2004). Further work is thus needed to determine whether the attentional demand associated with the use of fingertip touch for controlling posture is modified with practice by investigating the effect of a training period in healthy individuals, but also by testing blind individuals for whom the use of haptic information is the result of an everyday experience.

In summary, although the present findings showed that the use of fingertip touch improves postural control, they also suggested that the processing of this information make the regulation of postural sway more cognitively dependent. Considering that central processing factors are an important limitation for postural control, especially in individuals showing less accurate postural capacities (e.g., older adults) (see Woollacott and Shumway-Cook 2002, for a review), it is possible that the attentional demands associated with the use of a light fingertip touch could lead to decreased ability to maintain or recover balance in such a population (Bateni and Maki 2005). Such a proposal is yet speculative and warrants additional investigations.

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