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The degree of postural automaticity influences the prime movement and the anticipatory postural adjustments during standing in healthy young individuals

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ABSTRACT

Less attention to a balance task reduces the center of foot pressure (COP) variability by automating the task. However, it is not fully understood how the degree of postural automaticity influences the voluntary movement and anticipatory postural adjustments. Eleven healthy young adults performed a bipedal, eyes closed standing task under the three conditions: Control (C, standing task), Single (S, standing + reaction tasks), and Dual (D, standing + reaction + mental tasks). The reaction task was flexing the right shoulder to an auditory stimulus, which causes counter-clockwise rotational torque, and the mental task was arithmetic task. The COP variance before the reaction task was reduced in the D condition compared to that in the C and S conditions. On average the onsets of the arm movement and the vertical torque (Tz, anticipatory clockwise rotational torque) were both delayed, and the maximal Tz slope (the rate at which the torque develops) became less steep in the D condition compared to those in the S condition. When these data in the D condition were expressed as a percentage of those in the S condition, the arm movement onset and the Tz slope were positively and negatively, respectively, correlated with the COP variance. By using the mental-task induced COP variance reduction as the indicator of postural automaticity, our data suggest that the balance task for those with more COP variance reduction is less cognitively demanding, leading to the shorter reaction time probably due to the attention shift from the automated balance task to the reaction task.

1. Introduction

The amount of attention paid to a certain task greatly influences the performance of the task. For example, it has been shown that if the balance task becomes more challenging, the reaction time obtained while maintaining the equilibrium becomes longer (Vuillerme & Nougier, 2004). The delay in the reaction time is attributed to the fact that more difficult balance task requires more attention, and therefore less attention can be paid to the reaction task.

Another aspect of how attention can influence motor performance is related to the central nervous system's ability to perform a motor task automatically. It has been shown that performing a mental arithmetic task while standing can reduce the center of the foot pressure (COP) variability (Vuillerme & Vincent, 2006). The general explanation of this mental-task induced reduction in the COP variability is that performing the mental task takes the attention paid to the balance task away, and therefore the balance task becomes more automated. In this example, paying more attention has a rather detrimental effect. The specific underlying mechanisms are thought to be an increased stiffness and a reduced exploratory behavior (Vuillerme & Vincent, 2006).

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Anticipatory postural adjustments (APAs) are necessary for daily living. The voluntary movement performed determines the pattern of the APAs. For example, a rapid flexion of the right shoulder in standing causes the center of the body mass to move forward with a counter-clockwise rotational torque (when viewed from above) to the trunk. The APAs typically observed in this case is a backward shift of the COP and a vertical (rotational) torque centered around the COP (Tz) in the clockwise direction (Bleuse et al., 2005).

Although there are many studies in these topics, the relationships among the ability to automate a balance task, voluntary movement and APAs are not fully understood. For example, do those who automate the balance task more react faster in a reaction task because they can pay more attention to the reaction task compared to those who are less good at automating the balance task? Alternatively, do they react slower because their stiffness is increased (Vuillerme & Vincent, 2006) more? Finally, are the APAs differentially influenced by the degree of ability to automate the balance task? In order to answer these questions, we used the degree of the mental task-induced reduction in the COP variability in standing as the indicator of the degree of the ability to automate the balance task. The use of a simple reaction task under either a single task (standing alone) or a dual task (performing a mental task while standing) enabled us to investigate the relationships of the three parameters.

Therefore, the purpose of this study is to investigate how the degree of automaticity in a balance task influences the voluntary movement and APAs by comparing mental-task induced changes in the COP variability, reaction time and APAs. We hypothesized that those with more COP variability reduction are more influenced by the mental task, and therefore the reaction time delay is more pronounced compared to those with less COP variability reduction.

2. Methods

2.1. Subjects and general information

A total of 11 healthy young subjects (8 males) were recruited. The mean (and the standard deviation, SD) of their age was 26.2 ± 4.8 years old. They were all right handed.

Each of the subjects performed a standing balance task (50 s for each trial) under the following 3 conditions: Control (C), Single (S, reaction task only) and Dual (D, reaction and mental tasks) conditions. The experiment was approved by the local institutional review board and all subjects gave their written informed consent.

2.2. Instrumentation and experimental setup

Two force plates (9260AA, 500 mm × 600 mm, Kisler Instrument Corp., Winterthur, Switzerland) were used in the experiment, but the subjects stood only on one of the two plates with barefoot and eyes closed. The eye closure was visually checked by the investigators. The other plate was used only for creating the sound stimuli and recording the stimuli timing in the reaction task (see below). The standing posture was neutral (feet abducted about 30°, heals separated by about 3 cm, their arms hanging loosely by their sides), and the subjects were asked to sway as little as possible for the entire trials in all conditions. The force plate was reset before each trial, and the feet placement was maintained between trials.

The arm angular velocity with the reaction task was measured using a 6-axis motion sensor (MP-M6, MicroStone Co, Ltd., Saku, Japan). The sensor was attached using a double-sided adhesive tape on the dorsum of the right had.

The subjects were asked to flex their right shoulder as soon and quickly as possible to 90° after the sound stimulus. The sound stimuli were created by the investigator's striking the force plate on which the subjects were not standing.

In the D condition, the subjects were asked to perform a mental arithmetic task beginning at the data collection for each trial. The arithmetic problems were recorded in advance, and played using a computer. Twenty-one problems were presented every 2 s, and they were adding and subtracting a series of single-digit numbers (e.g., add 1 and 4, add 3, subtract 2,…). Subjects were instructed not to speak and move any parts of the body (Dault, Yardley, & Frank, 2003). The subjects performed the reaction task immediately after the 21st problem. The subjects were asked to remember the answer of the arithmetic task until the end of each trial. The subjects' answer was considered correct if the answer was within ± 2 of the true answer. The trial with a wrong answer was immediately discarded, and a new trial was collected. After recruiting all the 11 subjects, only 8 trials (about 15%) in total were repeated due to wrong answers (ranging from 0 to 2 for each subject).

The timing of the sound stimuli was always at around 42 s after the data collection started: However, the subjects were not told when they would hear the sound. In the S condition, the 42 s was long enough for the subjects to know when the stimuli were coming, and the stimuli were given at around 42 s, so it was not totally fixed. In the D condition, the stimuli were always given immediately after the 21st arithmetic problem. It would have been impossible for the subjects to count how many problems they had done, concurrently performing the arithmetic task.

2.3. Protocol

After attaching the motion sensor to the subjects' hand, they were asked to stand on the force plate. Then the location of their feet was marked for reproducibility. All subjects performed all the 3 conditions with a pseudo-random order across subjects. The numbers of trials for the conditions were 3, 5, and 5 for the C, S and D conditions, respectively, determined by our pilot study and the previous study (Vuillerme & Nougier, 2004). Enough rest (> 1 min for between-trials and > 5 min for between-conditions) was provided.