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Effects of light touch on postural sway and visual search accuracy: A test of functional integration and resource competition hypotheses

Fu-Chen Chen PhD[a,*], Hsin-Lin Chen graduate student (master degree)[a], Jui-Hung Tu PhD[b], Chia-Liang Tsai PhD[c]

[a] Department of Recreational Sport & Health Promotion, National Pingtung University of Science and Technology, Pingtung County, Taiwan
[b] Department of Physical Education, National Pingtung University, Pingtung County, Taiwan
[c] Institute of Physical Education, Health, and Leisure Studies, National Cheng Kung University, Tainan City, Taiwan

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ABSTRACT

People often multi-task in their daily life. However, the mechanisms for the interaction between simultaneous postural and non-postural tasks have been controversial over the years. The present study investigated the effects of light digital touch on both postural sway and visual search accuracy for the purpose of assessing two hypotheses (functional integration and resource competition), which may explain the interaction between postural sway and the performance of a non-postural task. Participants (n = 42, 20 male and 22 female) were asked to inspect a blank sheet of paper or visually search for target letters in a text block while a fingertip was in light contact with a stable surface (light touch, LT), or with both arms hanging at the sides of the body (no touch, NT). The results showed significant main effects of LT on reducing the magnitude of postural sway as well as enhancing visual search accuracy compared with the NT condition. The findings support the hypothesis of function integration, demonstrating that the modulation of postural sway can be modulated to improve the performance of a visual search task.

1. Introduction

Performing tasks simultaneously happens frequently throughout daily life (e.g., walking while holding a cup of coffee and standing while reading newspapers). A substantial quantity of literature has documented the relationship between postural control and the performance of simultaneous non-postural tasks (e.g., memory, counting and searching) [1–3]. Among them, Stoffregen et al. [4] found that the magnitude of postural sway was reduced when engaged in searching for designated letters in blocks of text compared with looking anywhere within the boundary of a blank sheet while quietly standing. The finding of reduced postural sway during the execution of a visual search task have been replicated in various populations such as the elderly, typically developing children, children with autism spectrum disorder, boxers, and crewmembers [5–9].

In order to explain those findings, Stoffregen et al. [4,10–12] proposed a hypothesis of functional integration arguing that postural sway can be adaptively tuned to facilitate the achievement of the other non-postural tasks. In this perspective, postural sway is reduced to fulfil the goal of a visual search task. According to this hypothesis, a reduction in postural sway should improve visual search performance. However, in Stoffregen et al.'s study, the standard of performance when searching targets or inspecting a blank sheet were not comparable due to the lack of a consistent dependent variable for both tasks. Therefore, we cannot clarify whether the reduction in postural sway would enhance the visual search performance or not. Further, the resource competition hypothesis conceptualises that postural control and simultaneous non-postural tasks compete for the allocation of a finite pool of central processing resources, leading to interference between tasks and likely performance degradation of any given task [1,13–15]. Based on the resource competition hypothesis, Stoffregen et al.'s findings can be interpreted to mean that individuals mainly allocate resources to postural adjustments and prioritise postural control over the visual search task, thereby reducing postural sway but leading to deteriorating visual search performance. Without a comparable dependent variable measuring visual performance for various experimental conditions, the mechanism, which explains the interaction between the control of postural sway and visual search performance, remains largely unknown.

* Corresponding author at: 1, Xuefu Road, Neipu Township, Pingtung County 912, Taiwan.
E-mail address: fcchen@mail.npust.edu.tw (F.-C. Chen).

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The objective of the present study was to test which hypothesis is feasible, i.e., functional integration and resource competition. To do this, we introduced a simultaneous light digital touch task to create a so-called triple-tasking context for the purpose of producing a comparable baseline condition regarding visual performance. Jeka and Lackner [16] have found that the light touch of only an index fingertip on a stable surface with a force less than 1 N can significantly reduce the magnitude of postural sway compared with the no-fingertip condition. In addition, it has been shown that the effects of a visual task (i.e., gaze at a target) and a light digital touch task on postural control are additive [17], and simultaneous visual and touch stimuli compete for a common limited-capacity processor [18]. Hence, we believe our manipulations provide a valid and fair test for both hypotheses.

Based on the resource competition hypothesis, the additional light digital touch task should inevitably result in a cost in processing capacities. If the overall demands of triple-tasking exceed the available processing capacities, then tasks should not suffer a deterioration in performance. Rather, if the overall demands surpass available processing capacities, then increased postural sway and/or degraded searching performance are anticipated. In short, the resource competition hypothesis predicts either unchanged or deteriorated performance during triple-tasking (light touch + visual search + postural control), as compared to dual-tasking (visual search + postural control). In contrast, the functional integration hypothesis predicts both decreased postural sway and improved searching performance while adding a light digital touch task. Since previous studies demonstrated that reduced sway can enhance the performance of concurrent non-postural tasks that require ocular stability and control (e.g., visual signal detection and affordance judgments) [2,19], we predicted the latter.

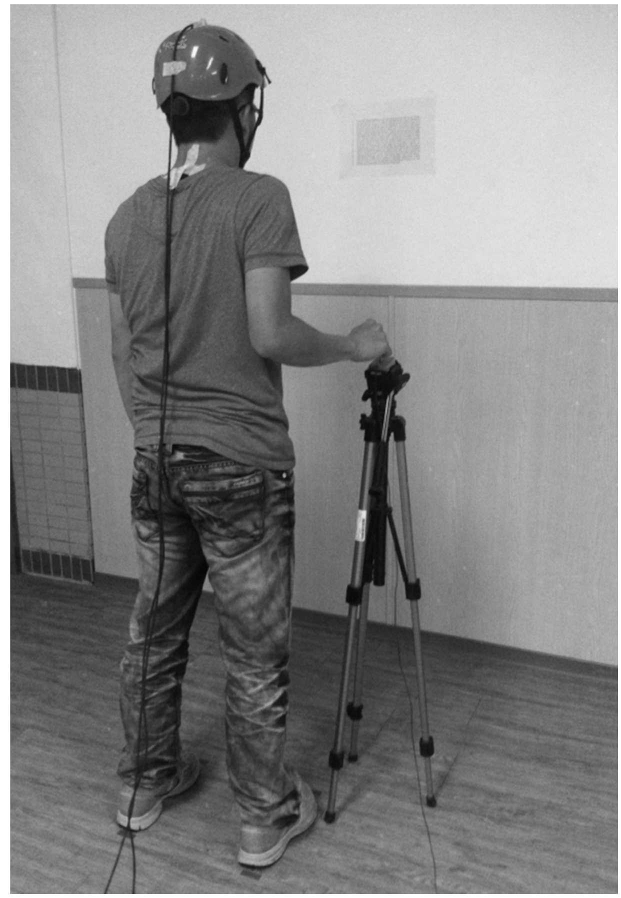

Fig. 1. Experimental setup.

2. Methods

The experimental procedures were approved by the Institutional Review Board at Antai Memorial Hospital (Pingtung County, Taiwan). All participants signed an informed consent document prior to the study.

2.1. Participants

Forty-two students (20 men and 22 women; age = 21.182 ± 1.775 years) recruited from the National Pingtung University of Science and Technology. Mean height was 168.633 ± 9.325 cm; mean weight was 65.484 ± 12.486 kg. All participants reported no known musculoskeletal injuries that could influence postural control. All were right-handed and had normal or corrected-to-normal vision.

2.2. Apparatus

The experimental setup is shown in Fig. 1. The movement data of the head and torso were collected via a magnetic tracking system (Fastrak, Polhemus, Inc., Colchester, VT), with one sensor attached to the top of a helmet worn by participants and another sensor attached to the centre of the back at the level of the C7 spinal process. The emitter was on a wooden stand (15 cm × 15 cm × 100 cm) positioned on back of the participants at a distance of 50 cm. The data were sampled at 60 Hz.

A 29.7 cm × 21 cm sheet of white paper was positioned at eye level in front of the participant at a distance of 100 cm with a visual angle of 11.5° × 7°. This paper size and distance were used because a previous study had indicated that when the angular change in gaze direction is less than 15°, gaze shifting is accomplished by eye movements [20]. Rather, a visual angle greater than 15° leads to excessive head rotation, which may further confound the effect of a light fingertip touch on postural sway. In the inspection task (IT), the target comprised a plain sheet of white paper, while in the visual search task (ST), the target comprised a sheet of white paper of the same size on which 13 lines of English text in 12-point Times New Roman font were printed.

A customised touch device consisted of a 5 cm × 5 cm touch plate connected to a strain gauge (LSB 200, Futek Advanced Sensor Technology, Inc., Irvine, CA) was used to determine the vertical touch force applied by the fingertip. This touch device was mounted on a tripod positioned at the participant's dominant (right) side. The height of the plate was adjusted to keep participant's right elbow flex at approximately 90° while using a fingertip to touch the plate [21]. We used an amplifier (CSG 110, Futek Advanced Sensor Technology, Inc.) to amplify and calibrate the signals from strain gauges in N. All force data were collected at 1000 Hz using LabView 2012 on a PC for later analysis.

2.3. Experimental protocol

Participants wearing sport shoes were tested while standing comfortably with feet shoulder-width apart. The position of the feet was marked with blue tape on the floor so that the stance width and angle were fixed throughout all trials for each participant. The mean stance width was 17.633 ± 5.136 cm and the mean stance angle was 14.526 ± 7.244°.

The Task condition consisted of two levels (IT and ST), and the touch condition consisted of two levels (no touch (NT) and light touch (LT)). There were four experimental conditions, IT + NT, IT + LT, ST + NT and ST + LT. During IT conditions, participants could look anywhere within the margins of the blank paper. During