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Effects and after-effects of voluntary intermittent light finger touch on body sway

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Effects of light touch on body sway have usually been investigated with some form of constant contact. Only two studies investigated transient sway dynamics following the addition or withdrawal of light touch. This study adopted a paradigm of intermittent touch and assessed body sway during as well as following short periods of touch of varying durations to investigate whether effects and after-effects of touch differ as a function of touch duration. In a modified heel-to-toe posture, 15 blindfolded participants alternated their index finger position between no-touching and touching on a strain gauge in response to low- and high-pitched auditory cues. Five trials of 46 s duration were segmented into 11 sections: a 6-s no-touching period was followed by five pseudo-randomly ordered touching periods of 0.5-, 1-, 1.5-, 2-, and 5-s duration, each of which was followed by another 6-s no-touching interval. Consistent with previous research, compared to no-touching intervals sway was reduced during touch periods with touch durations greater than 2 s. Progressive reductions in sway were evident after touch onset. After touch withdrawal in the 2-s touch condition, postural sway increased and returned to baseline level nearly immediately. Interestingly, in the 5-s touch condition, reductions in sway persisted even after touch withdrawal in the medio-lateral and antero-posterior plane for around 2.5 s and 5.5 s, respectively. Our intermittent touch paradigm resulted in duration-dependent touch effects and after-effects; the latter is a novel finding and may result from a more persistent postural set involved in proactive sway control.

1. Introduction

Lightly touching a reference object with the finger tip reduces postural sway even though the level of contact force is not sufficient to provide mechanical support [1]. It has been proposed that cutaneous afferent information from the contact provides cues that indicate own body sway [2]. Numerous studies have investigated the nature of this touch effect [3–12]. However, previous studies on the effect of light skin contact on body sway have focused on steady state contact only; except two [13,14] studies have probed the time course of body sway subsequent to touch onset or withdrawal.

The postural control system reweights all available sensory channels in order to optimize the sensorimotor control of stance in altered sensory environments [15]. Gain of a sensory channel is dynamically adjusted depending on a current estimate of its reliability as a reference for own body motion [16,17]. This dynamic function of gain adjustment is non-linear with regard to sensory perturbations [18,19]. Fast adaptation of the postural control system to the addition or withdrawal of light touch is critical in real life situations, as we may face intermittent availability of a support such as a handrail or furniture when moving through our environment. It is therefore important to study stabilization effects and after-effects of intermittent touches with varying durations, in order to see their impacts on postural control.

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Postural stabilization with finger tip tactile feedback has been shown to be a fast process. Rabin and colleagues [13] probed the time course of the light touch effect with a paradigm where finger tip light touch had to be established abruptly. They reported that upon contact body sway is exponentially reduced with a time constant of 1.6 s. In a more recent study, Sozzi and colleagues [14] adopted a paradigm with actively as well as passively initiated, abrupt addition or withdrawal transitions of visual or haptic afferent information. In the active transitions of haptic cues from no-touch to touch, they reported a latency of the onset of sway decrease of around 1.3 s with a time constant of 0.8 s. With regard to an after-effect following touch withdrawal, they observed a shorter latency of the onset of sway increase of just 1 s with a time constant of 0.8 s.

What these two studies above did not investigate, however, was whether the duration of touch exposure affects the dynamics of its after-effects on sway. Therefore, the aim of our current study, with an intermittent touching paradigm, was to investigate changes of body sway during as well as following short periods of touch of varying durations: 0.5, 1, 1.5, 2, and 5 s.

Based on previous studies [13,14], we expected that light touch contact is required to last between 1.5 and 2 s before a reduction in sway will become visible. Sozzi et al. [14] documented that a finite amount of time is necessary for central integration process after transition of touch contact. During this time the touch signal has to pass through several stages of processing [20], in which the signal must be disambiguated within the specific postural context and interpreted in an egocentric frame of reference. If postural adjustments follow the force signal by approximately 300 ms [2,21], it is reasonable to assume a period of 150–200 ms signal processing within supraspinal circuits. Based on the findings of Sozzi et al. [14], we assumed that sway would return to baseline levels following withdrawal within a time frame similar or shorter than the time required to integrate the touch signal.

2. Materials and methods

2.1. Participants

Fifteen healthy adults (eight females and seven males; average age 20.6 SD 2.64 years) gave their written informed consent, as approved by the Institutional Review Board of Chung Shan Medical University Hospital, to participate in the study. All of them were right-handed and reported no musculoskeletal and neurological abnormalities that could have influenced their standing balance.

2.2. Apparatus

A force plate (Bertec FP4550-08, USA) measured the six components of the ground reaction forces and moments to determine the medio-lateral and antero-posterior components of Centre-of-Pressure. A dual-axis strain-gauge (RMAX SN110336-1, Taiwan), which measured normal and lateral shear forces, formed the circular touch plate (5 cm diameter) with a smooth surface. In response to a high-pitched or low-pitched auditory cue, participants either made fingertip contact with the touch plate, mounted on a stand at waist level to the front right of the participants, or withdrew contact from the plate. Three infrared cameras (MotionAnalysis HAWK, USA) captured the motion of two reflective markers, one placed on the tip of participant's index finger and one on the edge of the touch plate. All signals were sampled at 100 Hz.

2.3. Procedure

Participants were asked to hold their index finger of the dominant hand above the touch plate while keeping the outstretched arm in a comfortable posture. Participants stood with bare feet in a modified heel-to-toe stance (the non-dominant heel touching the side of big toe of the dominant foot). Participants were then instructed to close their eyes, and to stand relaxed but as still as possible without speaking.

A single trial lasted for 46 s and consisted of a 6-s no-touching period (1st NT) followed by five touching periods of 0.5-, 1-, 1.5-, 2-, and 5-s duration (0.5, 1, 1.5, 2, and 5 T) in a pseudo-randomized order. Each of the five touch periods was followed by a 6-s no-touching period (2nd to 6th NT). The beginning and end of each trial was cued separately to indicate the starting and ending of data collection.

Trials were started when participants were ready. On hearing a high-pitched tone, participants flexed their index finger at the metacarpal-phalangeal joint to initiate light finger contact. On a low-pitched tone, participants extend their index finger just above the touch plate. Practice trials familiarized participants with the experimental protocol. Participants performed five standing trials and were allowed to rest for 30 s between trials.

2.4. Data analysis and statistics

All data underwent low-pass filtering with second-order Butterworth filter and 6 Hz cut-off frequency. According to the vertical touch force detected by the strain gauge, the onset and offset of each touching period was determined. Afterwards, data were divided into bins of 500 ms duration in order to standardize the number of data points for the sway measure extraction in different duration conditions. Due to the narrow bin width, we chose to analyse sway in terms of Centre-of-Pressure velocity (dCOP) as its variability measure would be less susceptible to voluntary low frequency drift than COP position. Also, a velocity-dependent signal resembles postural control better than position or acceleration under experimental conditions of sensory manipulation [22]. The standard deviation (SD) of dCOP in the medio-lateral ($dCOP_{ml}$) and antero-posterior ($dCOP_{ap}$) directions were calculated separately for the respective bins of interest and averaged for each duration condition across each of the five trials of a participant.

Using statistical software (SPSS 18.0, Chicago, IL, USA), firstly, we examined whether the recurring light touch would result in accumulated effects across a trial despite the interruptions. The change of sway across the no-touching periods irrespective of the inserted touch duration conditions, i.e., the last seven bins of the 1st NT and the first seven bins of the 2nd to 6th NT, was examined by two-way ANOVA (bin $\times$ sequence). Secondly, in order to examine touch effects two-way ANOVA (transition $\times$ duration) was conducted to compare the second to last NT bin before touch onset and the last bin of each touch duration conditions (0.5, 1, 1.5, 2, and 5 T). The bin just before touch onset was not chosen because during this bin the high-pitched cuing tone had occurred and the touching movement was in preparation. ANOVAs were followed up with simple contrasts to examine touch effects within each touch duration condition. Furthermore, the touch effects were fitted with linear regressions as a function of the five non-linear touch durations. Finally, for the specific duration conditions with significant touch effects, sway evolution after touch onset and withdrawal was evaluated by comparing the values of the respective touch bins with the 99% confidence interval (CI) of the first 11 bins of the 1st baseline NT. The significance level was set at 0.05.

3. Results

Overall, 52 out of 375 touch sections were excluded from data analysis, among which 21 had an average touch force greater than