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Can dancers suppress the haptically mediated interpersonal entrainment during rhythmic sway?

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ABSTRACT

Interpersonal entrainment emerges spontaneously when partners performing rhythmic movements together exchange sensory feedback about the other's movements. In this study, we asked whether couples of expert dancers, non-dancers and mixed couples can suppress the spontaneous haptically mediated inter-personal entrainment when their rhythmic sway is paced by differing metronome tempos. Fifty-four young participants formed three types of couples: nine dancer couples, consisting of individuals with at least eight years systematic practice in traditional Greek dance; nine non-dancer couples, consisting of individuals with no prior experience in dance and nine mixed couples, consisting of one dancer and one novice partner. Partners swayed rhythmically for 60 s, at different pacing frequencies (one at 0.25 Hz and the other at 0.35 Hz) under three haptic contact conditions: no contact between them; light fingertip touch established in the 2nd trial segment (30 s); and light fingertip touch released in the 2nd trial segment (30 s). Spectral analysis of the antero-posterior center of pressure displacement revealed that light touch increased the deviation of the dominant from the target (pacing) sway frequency, decreased the proportion of the signal's power at the target frequency and increased the coherence between the partners' sway signals (inter-personal coherence). These effects were specific to the mixed group whereas touch interference was weaker in non-dancers and absent in dancers. In addition, the coherence between the trial segments (intra-personal coherence) significantly decreased with touch only for the non-dancer while it remained unchanged for the dancer partner of the mixed group suggesting that the dancer was leading the non-dancer partner. It is concluded that systematic practice with traditional dance can modulate the spontaneous tendency towards haptically mediated interpersonal entrainment.

1. Introduction

Humans have the tendency to spontaneously coordinate their rhythmic actions with those of others when exchanging information by means of visual, auditory or tactile feedback. A characteristic example of this behavior is the audience's applause in a performance event (Neda, Ravasz, Brechet, Vicsek, & Barabasi, 2000). Experimentally, spontaneous interpersonal synchrony has been shown in visually coupled humans swinging hand help pendulums (Richardson, Marsh, & Schmidt, 2005; Schmidt & O'Brien, 1997) or rocking chairs together (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007). The interpersonal synchrony is stronger when partners are mechanically (Harrison & Richardson, 2009) or haptically (via hand holding) coupled while walking side by side or one in front of the other (Nessler & Gilliland, 2009; van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008; Zivotofsky & Hausdorff, 2007). Haptic contact by means of light fingertip touch between partners also evokes spontaneous entrainment in quiet standing (Johannsen, Guzman-Garcia, & Wing, 2009; Johannsen, Wing, & Hatzitaki, 2012) and rhythmic side by side sway (Sofianidis, Hatzitaki, Grouios, Johannsen, & Wing, 2012). In all cases, the emergent synchrony can be described by the dynamics of self-organized, coupled oscillators outlined in the Haken Kelso Bunz (HKB) model (Fuchs & Kelso, 1994; Haken, Kelso, & Bunz, 1985; Kelso & Jeka, 1992; Schmidt & Turvey, 1995). The strength of interpersonal entrainment, as this is reflected in the Relative Phase (RP) between the oscillating effectors, can be modulated by the individual oscillation frequencies (Nessler & Gilliland, 2009; Richardson et al., 2007), the sensory modality mediating contact (Nessler & Gilliland, 2009) and the partners' attention to the feedback stimulus (Richardson et al., 2007).

One question that naturally arises from the above evidence is whether humans are able to resist their spontaneous tendency towards entrainment. This might be necessary when someone does not want to entrain to the motion of his/her partner in contemporary dance or team sports performance. Experimental evidence suggests that this may not be an easy task. When partners rhythmically swinging hand held

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pendulums were explicitly instructed to continue performing at their preferred tempo after establishing visual contact, the rhythmic motions of the two pendulums were still attracted towards two stable coordination states at angles near 0° (in-phase) and 180° (anti-phase) (Richardson et al., 2007; Schmidt & O'Brien, 1997). Similarly, when partners seated across from each other were asked not to coordinate their rhythmic forearm oscillations, the cross-wavelet transform of their forearm oscillations revealed the emergence of an unintended co-ordination in the frequency domain (Issartel, Marin, & Cadopi, 2007). These results suggest that humans engaged in rhythmic actions are unable to avoid the visually evoked spontaneous interpersonal entrainment even when asked to do it *intentionally*. To our knowledge however, this hypothesis has not been tested when partners are haptically coupled.

Expertise in movement timing acquired through dance practice might be one way to overcome the spontaneous tendency for interpersonal entrainment. After years of training, expert ballet dancers have learned to control the body's degrees of freedom (Lepelley, Thullier, Koral, & Lestienne, 2006; Thullier & Moufti, 2004) by building an internal movement plan which enables better accuracy of their actions in time and synchronization to the beat of the metronome or music (Miura, Kudo, Ohtsuki, & Kanehisa, 2011). In addition, traditional Greek dancers have demonstrated an improved ability to integrate interpersonal touch with auditory (metronome) information for synchronizing with their partner when sway was commonly paced for partners (Sofianidis et al., 2012). On the other hand, it has been suggested that expert contemporary dancers can *intentionally* avoid the visually evoked spontaneous entrainment to their partner when asked to do so, whereas non-dancers cannot (Issartel, Marin, & Cadopi, 2006). It is not clear however whether the ability to overcome spontaneous interpersonal entrainment relates to the nature of the practiced rhythmic activity (i.e. type of dance), the type of the perceptual linkage between partners (i.e. visual, auditory or kinesthetic) or other task constraints such as the individual pacing frequencies (or tempos).

To address these questions, we asked whether experts of traditional Greek dance can suppress the haptically mediated spontaneous interpersonal entrainment during periodic sway in the sagittal plane. Instead of asking partners to *intentionally* resist their tendency towards entrainment, we introduced different pacing (i.e. metronome) frequencies between partners as a control parameter to facilitate the suppression of entrainment. Auditory (i.e. metronome) cueing produces stronger and more stable sensory–motor synchronization patterns compared to visual or haptic cues (Sejdic, Fu, Pak, Fairley, & Chau, 2012). Traditional Greek dance on the other hand promotes the concurrent synchronization to the music and to the other dancers by means of visual and haptic (via hand holding) feedback. Based on our prediction, dancers would be less entrained with touch compared to non-dancers because they have learned to prioritize synchronization to the music while paying less attention to the other group members' movements. To investigate the direction of entrainment, a third type of couple consisting of one dancer and one non-dancer partner was tested. We hypothesized that the non-dancer would be attracted towards the dancer's frequency because the non-dancer's sway is externally driven by sensory feedback in contrast to the dancer's sway that is internally controlled by a prior motor plan.

2. Method

2.1. Participants

Fifty four (54) healthy adults divided into three groups based on their previous dance experience, volunteered to participate in this study. All participants were free from any neurological or musculoskeletal impairment. The first group [Experts Group, age: 23.55 ± 3.97 years, 6 males and 12 females] consisted of 9 couples of experienced dancers (having at least eight years of systematic practice in traditional Greek dance). The second group [mixed group, age: 26.72 ± 5.37 years, 6 males and 12 females] consisted of 9 couples in which one partner was an experienced dancer (having at least eight years of systematic practice in traditional Greek dance) while the other was a novice participant with no prior experience in any type of dance. The third group (Novice Group, age: 24.85 ± 4.69 years, 6 males and 12 females) consisted of 9 couples in which both partners had no previous dance experience. The groups were counter balanced for age and gender. Partners in each couple were of the same gender, similar height and mass and did not know each other prior to the experiment.

To maintain the single-blind nature of this study, an elaborate cover story was used. The story was designed to distract participants from the experiment's true purpose, while explaining all aspects of the experiment in a plausible manner and capturing the attention of the participants so that they would be alert and responsive to the experimental events [for a detailed description of the cover story see (Sofianidis et al., 2012)]. Once the participants understood the (desired) aim of the study they completed an informed consent form. All experimental procedures and protocols were carried out according to the ethical guidelines of the Institutional President's Committee on Ethical Consideration in Human Experimentation, conforming to the Revised Helsinki Declaration of 2000.

2.2. Apparatus

Two adjacent force plates (Balance Plate 6501, Bertec Corp., Columbus, USA, 100 Hz) were used to record the ground reaction forces and moments during performance of the rhythmic sway task. A reflective marker was attached to the tip of the index finger of each partner. In addition, the Matlab Timing Analysis Package, MatTAP, (Elliott, Welchman, & Wing, 2009) was used to generate the auditory (metronome) cues that were used to pace the rhythmic sway during the experiment. The ground reaction forces, metronome signals and 3D position coordinates of the fingertip markers of the partners were synchronously sampled at 100 Hz using a 10 camera motion analysis system that was connected to an A/D card (Vicon-T40, Oxford, UK, 100 Hz).

2.3. Task and procedure

Participants were tested in couples. They wore a set of binaural earphones (Stereo Headphones HD3030) in order to listen to the periodic auditory tone that was used to guide the sway task and block any sounds other than this cue. The two partners stood on adjacent force platforms next to each other (shoulder to shoulder distance: 10 cm) while facing forward adopting a natural bipedal quiet stance position (feet flat and parallel, inter-malleolar distance at 10 cm; Fig. 1a). Partners were randomly assigned to the force platforms with the exception of those in the mixed group, in which the expert dancer was always positioned on the left force platform. A reflective marker was attached to the tip of the index finger (to the right index finger for the partner standing on the right platform and to the left index finger for the partner standing on the left platform).

The experimental task required periodically swaying the body (by shifting body weight) in the Anterior/Posterior (AP) direction for 60 s under the auditory guidance of a computer generated metronome tone signal (tone duration: 30 ms, tone frequency: 800 Hz) delivered through the earphones. Each partner was instructed to sway back and forth aligning the maximum forward and backward leaning positions with each successive beep of the metronome while keeping the body straight, the upper arms in full contact with the sides of the trunk and the elbows flexed at a 90° angle, the feet flat on the platform (with no elevation of either the toes or heels). The eyes were closed all the time during task performance in order to isolate auditory and haptic cues. Two target frequencies, classified as Slow (0.25 Hz) and Fast (0.35 Hz) based on prior experiments and pilot testing, were used to guide