Intention to Sway Stabilizes Postural Coordination

Olivier Oullier [1], **Benoît G. Bardy** [2,3], **Reinoud J. Bootsma** [1], **& Thomas A. Stoffregen** [4]

[1] Movement & Perception Lab, CNRS-Université de la Méditerranée, Marseille, France
[2] Research Center in Sport Sciences, Université de Paris XI, Orsay, France
[3] Institut Universitaire de France
[4] Human Factors Research Lab, University of Minnesota, Minneapolis, USA

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In several experiments, participants have been asked to move their head intentionally so as to track the motion of a visual target (e.g. Bardy et al., 2002). They were not given any instructions about postural control *per se*; rather, postural coordination emerged as a means to achieve the required supra-postural tracking task. The motion of different body segments underlying the movement of the head has been analyzed by focusing on the relative phase ϕ between rotations around the ankles and hips. When tracking a target that oscillates at low frequencies, participants were found to spontaneously adopt an in-phase pattern ($\phi \approx 20°$), while tracking at higher frequencies of target motion lead to the adoption of an antiphase pattern ($\phi \approx 180°$). Interestingly, transitions from one postural mode to the other - evoked by a gradual change in target frequency - exhibited typical signatures of self-organized systems: differential stability, critical fluctuations, phase transitions, critical slowing and hysteresis (Bardy et al., 2002).

In addition to these findings, manipulation of various parameters revealed that postural coordination dynamics emerge from the interaction of constraints falling into different classes; mainly those arising from properties of the environment, from the body, and from the goal of the task (see Oullier et al., 2004 for a review). Previous research has shown that, separately, environmental and bodily constraints can provoke qualitative changes in the dynamics of the postural system. For instance, the mechanical constraints imposed by standing on a narrow beam (therefore reducing the surface of support) favour the antiphase pattern (Marin et al., 1999). However, little is known regarding how intention to sway (or not) affects postural coordination dynamics. For instance, whether the preferred in-phase and antiphase postural modes of coordination emerge when participants do not intentionally sway remains uncertain.

In the present study, we address this question by simultaneously varying intentional and mechanical constraints to examine the possible effects of their (competitive/cooperative) interactions on postural coordination dynamics.

Methods

Participants stood barefooted in a moving room, arms folded on their chest facing a target attached to the front wall at eye level. Motion around the neck and the knee axes were restricted with adhesive tape. The room was oscillating back and forth in the anterior-posterior axis with a constant peak-to-peak amplitude (4 cm). Its frequency was varied within a trial increasing or decreasing between 0.15 and 0.75 Hz in 0.05 Hz steps. Each frequency plateau lasted 10 cycles. Data from these increasing and decreasing trials were collapsed *a posteriori* to control for possible hysteresis effects. Participants (N = 42) were randomly divided into four groups (N = 13). To avoid fatigue effects (one trial lasting approximately for 8 minutes) each group performed one of four experimental conditions resulting from fully crossing two *intention* conditions with two *support surface* conditions.

Intention was manipulated by asking participants to simply look at the target while the room was oscillating (looking conditions) or to intentionally maintain a constant target-head gain (ideally 1) and phase (ideally 0°; tracking conditions). Surface support was manipulated by asking participants to either perform the looking and tracking tasks while standing on the concrete floor of the laboratory (floor conditions) or standing on a 10-cm narrow beam (beam conditions), i.e. shorter than the length of their feet. Because of format restrictions only the results concerning the (point-estimate) ankle-hip relative phase ϕ and its circular deviation will be presented here.

Results

Floor. When performing the tasks on the floor a clearly bimodal distribution of relative phase values was observed (Figures 1A&B). For the looking and the tracking tasks, the in-phase (close to 20°) and the antiphase (close to 180°) postural coordination modes were adopted for low and high frequencies of the moving room, respectively, as consistently found in our previous work (e.g. Bardy et al., 2002). This finding suggests that, when standing on the concrete floor, postural coordination patterns adopted to perform an intentional or a non-intentional supra-postural task are similar. Interestingly, the values of circular deviation found for both coordination patterns in the tracking tasks were significantly smaller compared to those of the same two patterns adopted in the looking condition. This result clearly indicates that when standing on the floor, the intention to sway had a stabilizing effect on postural coordination (Oullier et al., 2002).

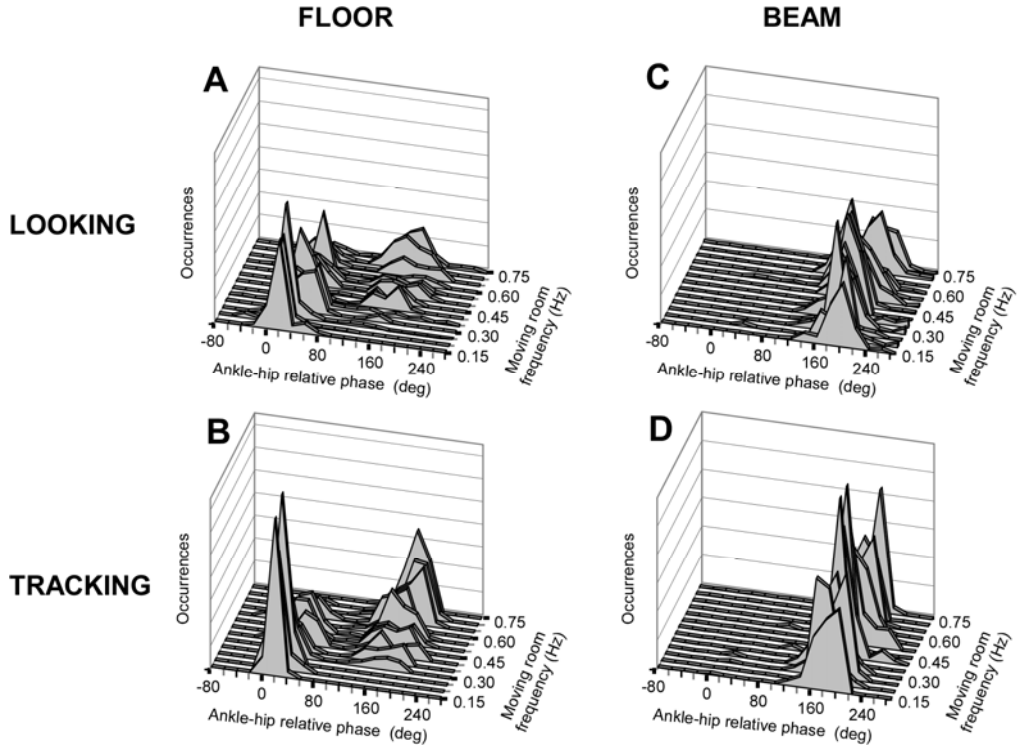

Figure 1. Frequency distribution of ankle-hip relative phase □values as a function of the room frequency (all individual □ values were sorted in 20° bins). A) Looking task performed on the floor, B) Tracking task performed on the floor (adapted from Oullier et al., 2002). C) Looking task performed on the beam, D) Tracking task performed on the beam (adapted from Oullier et al., 2004).

Beam. Our results replicate those of Marin et al. (1999), since when standing on the beam the antiphase pattern was the only one adopted regardless of the intention to move. However, the analysis of the circular deviation of ϕ revealead that the antiphase pattern, adopted in the execution of both tasks, was more variable when looking than when tracking (see Figures 1C and D). This result suggests that similarly to the 'floor' results, coordination was more stable when tracking the target in spite of the compelling effect imposed by standing on a narrow beam (Oullier et al., 2004). This stabilizing effect found when tracking was confirmed by the difference between the number of falls from the beam in each task (10 in the looking group against 3 in the tracking group).

Discussion

Bardy et al. (1999, 2002) documented the emergence of two preferred modes of postural coordination when participants used voluntary movements of the head to track motion of a target in the antero-posterior axis. The present results suggest that similar modes emerge whether participants standing on the floor track the target, or merely look at it. Thus, coordination dynamics underlying the maintenance of upright stance appears similar regardless of the intention to sway, therefore challenging the distinction between quiet stance and sway (Creath et al., 2005). The beam exercised a powerful influence on coordination but, despite this mechanically-based effect, coupling of head motion with room motion was strongly modulated by the manipulation in supra-postural task instructions, i.e. intention. The persistence of supra-postural task effects despite the constraining influence of the beam is the most important result of this study. As to the role played by each constraint (frequency, surface of support and intention) on the postural system, it seems that in spite of a strong mechanical effect of standing on a beam, the effect of intention does not disappear. Therefore, the present results indicate a coexistence between the environmental (beam) and intentional (looking versus tracking) constraints, rather than one constraint being overwhelmed by the other. The strong mechanical constraint exercised by the beam did not annihilate the stabilizing effect of intention (Oullier et al., 2004). These results further attest that (postural) coordination dynamics emerge from a coalition of constraints of different nature.

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