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Influence of heading perception in the control of posture

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ABSTRACT

The optic flow visual input directly influences the postural control. The aim of the present study was to examine the relationship between visually induced heading perception and postural stability, using optic flow stimulation. The dots were accelerated to simulate a heading direction to the left or to the right of the vertical midline. The participants were instructed to indicate the perceived optic flow direction by making a saccade to the simulated heading direction. We simultaneously acquired electromyographyc and center of pressure (COP) signals. We analysed the postural sway during three different epochs: (i) the first 500 ms after the stimulus onset, (ii) 500 ms before saccade onset, epoch in which the perception is achieved and, (iii) 500 ms after saccade onset. Participants exhibited a greater postural instability before the saccade, when the perception of heading was achieved, and the sway increased further after the saccade. These results indicate that the conscious representation of the self-motion affects the neural control of posture more than the mere visual motion, producing more instability when visual signals are contrasting with eye movements. It could be that part of these effects are due to the interactions between gaze shift and optic flow.

1. Introduction

Vision, together with somatosensory and vestibular systems, is an important component of the neural control of posture and locomotion. The visual system is influenced not only by what subject sees (focal mode), but also by the information that comes from the surrounding objects during the body's motion (ambient mode) (Wade and Jones, 1997). The focal mode is responsible for object recognition, while the ambient mode for orientation and locomotion (Post et al., 1970). Looking under different angular standpoints modulates neural signal processing in various brain areas involved in planning movement, and affects various parameters of postural and motor tasks performance (Bédard et al., 2008). Research on postural control has focused on the perceptual information used for the adaptive control of action (Schöner, 1991). Postural responses relies on multisensory information, in which several cerebral regions are responsible for both eye movements and posture, meanwhile, other brain regions integrate sensory input during postural tasks (Leigh and Zee, 2013).

The optic flow causes specific postural responses (Persiani et al., 2015; Raffi et al., 2017, 2014b) and is an important cue for heading perception (Piras et al., 2016); indeed, when standing people are exposed to artificially generated optic flow, they tend to respond with postural oscillations (Persiani et al., 2015; Raffi et al., 2017, 2014b). Sensorimotor control of stable upright posture, head and eye movement, relies on afferent information from the vestibular, visual and proprioceptive systems, which converge in several areas throughout the central nervous system. Brandt et al. (1999), examining the role of eye movement on postural control, found that horizontal saccades of 5–80° deteriorated postural stabilization relative to fixation condition and the deterioration increased with the saccades amplitude. These variations in amplitude are consistent with the eye movement literature, which has documented the use of head rotations when gaze shifts exceed 15° (Brandt, 1999). Studying the relationship between optic flow and postural control, an important aspect links the optic flow perception to the visual stabilization of posture. In the present study, we sought to clarify the effect of increased perceptual resources on the ability to maintain stability during a task in which subjects had to judge between two possible visually perceived self-motion directions. Perception of self-motion by radial flow occurs in at least two stages of analysis: (i) an early stage of local-motion analysis, and (ii) a later global-motion integration stage (Burr and Santoro, 2001). Therefore, we hypothesise that during the period in which subjects have built the conscious perception of the self-motion direction, postural responses could be differently modulated than during the initial period of pure global visual stimulation. In fact, the processing of the retinal input during the two epochs might involves different parts of the brain (subcortical vs. cortical). The postural responses to these different conditions were examined by measuring electromyographic responses and several parameters of the center of pressure (COP). Moreover, in the field of postural control, an important issue to keep into account is the gender

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difference, given that women are at greater risk of injurious falls (Overstall et al., 1977). To date, there are discrepancies in the literature. Few studies reported that women showed more body sway than men (Panzer et al., 1995; Yoshida et al., 1983), while some other papers reported opposed results (Era et al., 2006; Masui et al., 2005; Persiani et al., 2015) or no gender differences (Bryant et al., 2005). These discrepancies in the literature likely arise from methodological issues, such as differences in testing postures (static or dynamic) in the visual stimulation, or in the time sequence of the tasks. Tinetti and co-workers (1988) reported that women make more frequent medio-lateral weight shifts than men. Following their results, we sought to elucidate if a saccadic eye movement toward a peripheral target modulates the medio-lateral sway. Thus, we investigated the postural responses in both males and females trying to deepen the different mechanisms used in postural control during visual perception.

2. Methods

2.1. Participants

Twenty-four healthy volunteers, 12 females and 12 males (22.58 ± 2.3 years) participated in the study. Subjects were the same as those in the previous study (Piras et al., 2016; Raffi et al., 2017), The average height and weight for females were (166.8 ± 5.7 cm, 57.8 ± 5 kg) and for males (177.3 ± 5.4 cm and 79 ± 11 kg). The outcome of the laterality questionnaire revealed that all subjects were right side dominant:

$$[(\textbf{right preference} - \textbf{left preference}) / (\textbf{right preference} + \textbf{left preference})] \times \textbf{100}$$

A positive laterality index was indicative of a right dominance, while a negative laterality index was indicative of a left dominance. All subjects had normal vision and a written informed consent was signed before the beginnings of recordings. The experimental protocol was approved by the Institutional Ethic Committee of the University of Bologna. The experiments have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

2.2. Apparatus

The procedure was similar to that on a previous paper (Raffi et al., 2014b). At the beginning of the experiment, subjects were prepared for the electromyographyc recordings. The skin was shaved and cleaned before placing the electrodes to improve the contact with the skin. Ag/AgCl disposable electrodes 32 × 32 mm with an active area of 0.8 cm^2 and an inter-electrode distance of about 2 cm (RAM medical instrument s.r.l., Italy) were used in a bipolar configuration. Electrodes were positioned on the muscular belly of: right tibialis anterior (RTA), left tibialis anterior (LTA), right soleus (RSOL), left soleus (LSOL), right vastus medialis (RVM), left vastus medialis (LVM), right biceps femoris (RBF), left biceps femoris (LBF), right rectus femoris (RRF), left rectus femoris (LRF), right erector spinae (RERS), left erector spinae (LERS). The reference electrode was placed on the malleolus bone (electrically neutral tissue). EMG data were acquired by a Pocket EMG (BTS Bioengineering Inc., Italy). After placing the electrodes, we acquired the maximum voluntary contraction (MVC) in which each subject had to perform, for 5 s, an isometric contraction against a maximum load using isotonic machines (Technogym, Italy).

The stabilometric data were acquired using two Kistler force platforms of 40x60 cm (no. 9286BA, BTS bioengineering, Italy). Subjects had to stay barefoot, in a comfortable position, with each foot placed on each platform, in a straight forward position and distant 20 cm each other. Each foot was placed on a separate platform to analyse limb asymmetry.

Eye movements were recorded binocularly by a video-based eye tracking system (EyeLink II; SR Research, Canada). The system consisted of two miniature cameras mounted on a leather-padded headband. Pupil tracking was performed at 500 samples/s, with high spatial resolution (< 0.005°) and low noise (< 0.01°). The eye tracker was calibrated and validated in a three-point grid horizontally at the beginning of the experiment and every 4 videos.

2.3. Optic flow stimuli and procedure

Expanding optic flow stimuli were presented full field by a retro video projector (Sony VPL EX3) positioned 415 cm away from a translucent screen. The screen covered 135 × 107° of visual field and was placed 115 cm from the subjects' eyes. Optic flow stimuli were made by white dots of a width of 0.4° and of a luminous intensity of 1.3 cd/m^2. We presented two types of optic flow motion: in the first condition the dots were accelerated to the left hemifield, to simulate a left heading, while in the second condition the speed was accelerated to the right to simulate right heading (Regan and Beverley, 1982). The left or right portion of the optic flow was accelerated from the beginning of the task. To study the interaction between postural and fixation position responses, we presented the optic flow motion together with three fixation points 0.8° in width (Fig. 1): one at the center of the screen (condition for starting the experiment), one to the right (20°) and one to the left (20°). Optic flow stimuli were made using Matlab psychophysical toolbox (The Mathworks Inc., Natick, MA, United States).

During recordings, all instruments were synchronized together. The EyeLink system, via the SceneLink software, was responsible for stimuli presentation and eye movement recordings. At the stimulus onset, the EyeLink system sent a TTL signal to the BTS SMART system, which managed the acquisition of EMG and stabilometric data.

All experiments were performed in a dark room. The fixation point position on the center of the screen was adjusted according to the height of each subject. At the stimulus onset, the participants had to

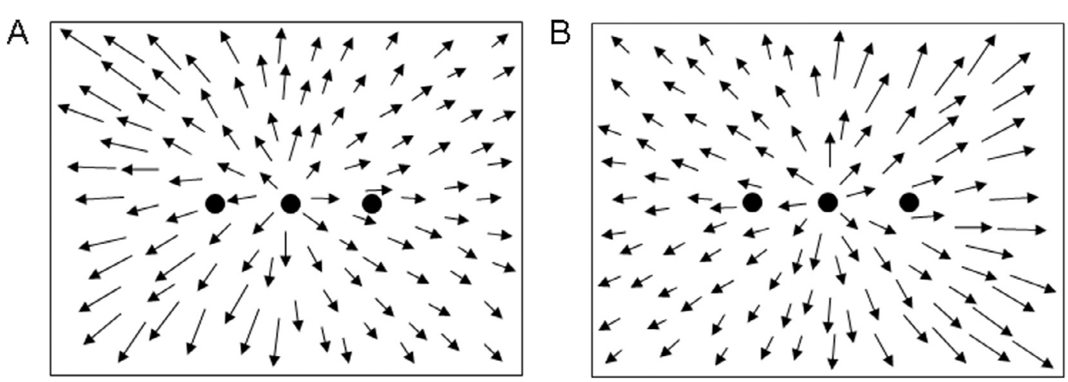

Fig. 1. Optic flow stimuli. Dots speed was accelerated in the left hemifield to simulate a left motion direction (A) or in the right hemifield to simulate a right motion direction (B). The three fixation points were always presented at center of the screen, 20° to the right and 20° to the left.