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How trunk turns affect locomotion when you are not looking where you go

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ABSTRACT

How well do we maintain heading direction during walking while we look at objects beside our path by rotating our eyes, head, or trunk? Common experience indicates that it may be fairly hazardous not to look where you are going. In the present study, 12 young adults walked on a treadmill while they followed a moving dot along a horizontal line with their gaze by rotating primarily either their eyes, head, or trunk for amplitudes of up to 25°. During walking the movement of the center of pressure (COP) was monitored using force transducers under a treadmill. Under normal light conditions, the participants showed little lateral deviation of the COP from the heading direction when they performed the eye or head movement task during walking, even when optic flow information was limited. In contrast, trunk rotations led to a doubling of the COP deviation in the mediolateral direction. Some of this deviation was attributed to foot rotation. Participants tended to point their feet in the gaze direction when making trunk turns. The tendency of the feet to be aligned with the trunk is likely to be due to a preference to have feet and body in the same orientation. Such alignment is weaker for the feet with respect to head position and it is absent with respect to eye position. It is argued that feet and trunk orientation are normally tightly coupled during

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gait and that it requires special abilities to move both segments independently when walking.

1. Introduction

Clinicians indicate that falls in the elderly often are related to participants looking sideways while walking (Shumway-Cook, personal communication). Although there are very good reasons to look where you go (Wann & Swapp, 2000), most participants frequently track objects on the side while walking (Patla & Vickers, 1997). This results in eye, head, or even trunk rotations, which complicate the task for participants to evaluate their direction of heading on the basis of retinal optic flow (Gibson, 1950; for review see Lappe, Bremmer, & van den Berg, 1999). Several psychophysical studies have investigated this using seated participants. It was found that heading judgment errors, made while viewing optic flow displays suggesting forward motion, were small even if smooth pursuit eye movements were added (Banks, Ehrlich, Backus, & Crowell, 1996; Royden, Banks, & Crowell, 1992; Royden, Crowell, & Banks, 1994). Similarly, Crowell, Banks, Shenoy, and Andersen (1998) found that heading judgment was better for true head movements than for simulated ones (using optic flow). Wilkie and Wann (2003) found that steering with active gaze is much more accurate than with fixed gaze.

Simple extrapolation from psychophysical data to gait is not possible because heading direction during real walking is not governed solely by visual input and extraretinal cues (efference copies of oculomotor commands), but also by other sources, such as vestibular input and somatosensory information (from the legs and feet). Therefore some of these questions have been tested in real gait studies (Rushton, Harris, Lloyd, & Wann, 1998; Schubert, Bohner, Berger, van Sprundel, & Duysens, 2003; Warren, Kay, Zosh, Duchon, & Sahuc, 2001). Overall, the real gait data fitted well with the psychophysics' predictions. In the Schubert et al. study the participants were asked to maintain heading direction while walking on a treadmill while they followed a horizontally moving dot either with the head or with their eyes. It was found in all experiments that lateral sway amplitude was quite limited (as predicted by the psychophysics) but increased linearly with the increasing excursion of the visual target. Different strategies to perform the gaze shift (eye or head turns) only resulted in minor differences in lateral sway amplitude.

In a next step, we have now examined the effects of trunk turns on heading judgment. Trunk turns are not frequently made during gait, presumably because eye and/or head turns can be used instead. Nevertheless, there are situations in which such trunk turns are made (for example in elderly because of stiffening of the spine). Maintaining heading direction during such large continuous trunk turns is quite demanding because of the complexities of the computations involved (trunk versus leg position; Mergner, Siebold, Schweigart, & Becker, 1992). Various coordinate transformations are required since the somatosensory inflow from the feet (interface with the ground surface) has to be evaluated with respect to position of the upper body (proprioceptors in trunk muscles), then to head-on-shoulder (neck proprioceptors, vestibular organ), to eye-in-head and finally to retinal coordinates. This complexity may explain why gaze changes are mostly performed without trunk rotations except for gaze changes at large eccentricities (Radau, Tweed, & Vilis, 1994). A further complication is that one is used to align body and feet and that trunk turns during gait may induce foot rotations in an attempt to keep the feet aligned to the trunk. This leads to very unusual feedback from the feet, which normally point towards the heading direction.

Given these complications, the question was asked how gait is affected when untrained participants make trunk turns in order to direct gaze away from the heading direction. It was hypothesized that trunk turns could lead to greater instability than eye or head turns. This hypothesis was tested in a group of young adults walking on a treadmill. They had to keep their heading direction while following a target in front of them as it moved horizontally and away from the midline at various amplitudes (similar to the experiments described by Schubert et al., 2003). There were three conditions, corresponding to the participants following the target with movements either of the eyes, the head or the trunk. The stability of the participants was evaluated using force transducers under the treadmill, allowing the calculation of the COP.