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Research article

# Visually fixating or tracking another person decreases balance control in young and older females walking in a real-world scenario

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ABSTRACT

Balance control during overground walking was assessed in 10 young (23.6 ± 3.4) and 10 older (71.0 ± 5.5 years) healthy females during free gaze, and when fixating or tracking another person in an everyday use waiting room. Balance control was characterised by medial/lateral sacrum acceleration dispersion, and gaze fixations were simultaneously assessed with eye tracking equipment. The results showed decreased balance control when fixating a stationary ($p = 0.003$, $g_{av} = 0.19$) and tracking a walking ($p = 0.027$, $g_{av} = 0.16$) person compared to free gaze. The older adults exhibited reduced baseline stability throughout, but the decrease caused by the visual tasks was not more profound than the younger adults. The decreased balance control when fixating on or tracking the observed person was likely due to more challenging conditions for interpreting retinal flow, which facilitated less reliable estimates of self-motion through vision. The older adults either processed retinal flow during the tasks as effectively as the young adults, or they adopted a more rigid posture to facilitate visual stability, which masked any ageing effect of the visual tasks. The decrease in balance control, the first to be shown in this context, may warrant further investigation in those with ocular or vestibular dysfunction.

## 1. Introduction

Vision helps maintain an upright posture during locomotion [1,2]. This is facilitated by changes in patterns of light intensities caused by relative motion between an observer and their environment, which are sensed at the retina. Lateral trunk lean, for example, would generate a translational flow on the retina in the opposite direction [3]. The central nervous system uses this to estimate shifts in body position and initiate postural adjustments [4]. Eye movements can change the structure of retinal flow, and this has previously been suggested to affect balance control during locomotion. That is, visually tracking a moving target with smooth pursuits led to increased medial/lateral (ML) trunk movement and step-width variability in young and older adults [5]. During such eye movements, although the target of fixation is stabilised on the fovea, the background information invariably shifts on the retina in the direction opposite to the eye rotation [6]. This seems to make it more difficult to estimate self-motion through visual means, which is similar to that shown in standing experiments [7–9].

During our previous investigation [5], the visual target was projected in 2D at one end of the laboratory. Humans often, however, fixate and track 3D objects located more in the foreground, such as another standing or walking person in the field of view [10]. This would change the structure of retinal flow when compared to a 2D target. Because the person would be closer to the observer relative to the background, there would be defocus blur to regions immediately surrounding the person [10]. Furthermore, the relative distance would generate motion parallax, with the retinal image of the region behind the person shifting in the direction of the observer's movements [11]. Of interest is whether these factors would generate a different balance response in an observer when compared to our previous investigation.

Previous studies examining parallax and balance control during locomotion have typically used corridor style paradigms [12,13]. These do not create the same defocus blur or parallax which would occur when fixating a single object ahead of the observer, such as another person. Predicting what effect fixating another person would have on balance control during locomotion is thus difficult. However, some evidence can be taken from standing experiments. These typically show improvements to postural control when fixating a single near target in relation to the background. The extra parallax cues are thought to provide 'richer' retinal information to make postural adjustments

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against (for a review see [4]). Therefore, it is feasible that the parallax caused by fixating a standing person (whilst the observer is walking) could maintain or improve balance in the observer when compared to no person being present. On the other hand, if the person being observed walked perpendicular to the observer's heading direction, a smooth pursuit would be needed to track them. Thus, retinal flow would consist of a combination of radial expansion from forward progression, and horizontal flow from the eye rotation [14]. Similar to our previous experiment [5], this would resemble a curved movement with a shifting focus of expansion [14]. Although there are compensatory mechanisms against retinal image motion during smooth pursuits to maintain perceptual stability [6,15], these are imperfect. For instance, there have been documented declines in motion sensitivity [16], and temporal contrast sensitivity to moving stimuli [17]. Ultimately, the altered flow could lead to less accurate visual detection of self-motion, and this could cause a decrease in balance control despite the parallax cues which would be present.

If tracking a walking person is shown to decrease balance control, it could have important implications in older adults. Older adults have been shown to have a reduced ability to decouple retinal flow caused by external motion from that caused by self-motion, potentially due to somatosensory processing declines [18]. Further, this has been shown to decrease stability during locomotion [19]. Therefore, if older adults are less able to process retinal flow during the smooth pursuit to track a walking person, it could lead to a bigger decrease in stability when compared to young adults. Moreover, although our previous laboratory investigation showed a similar decrease to balance control in young and older adults tracking a 2D target, the older adults were already exhibiting lower baseline stability. This is typical in healthy older populations. Any further decrease to balance control caused by tracking a person, regardless of comparison to young adults, would thus be undesirable.

The present investigation assessed balance control during walking in young and older adults during free gaze, and when visually fixating or tracking a standing or walking person in a real-world environment. Balance was characterised by ML Sacrum acceleration dispersion. It was hypothesised: 1) Visually fixating a standing person would maintain or improve balance control due to more information from parallax; 2) balance would be decreased when the observed person was walking owing to altered retinal flow patterns; 3) the decreased balance caused by tracking the person would be more profound in the older adults, and the older adults would exhibit less baseline stability throughout testing.

## 2. Methodology

### 2.1. Participants

Ten young (mean ± SD: age: 23.6 ± 3.4 years, height: 1.68 ± 5.8 m, mass: 69.0 ± 9.9 kg) and 10 older (mean ± SD: age: 71.0 ± 5.5 years, height: 161.2 ± 5.5 m, mass: 63.9 ± 10.3 kg) healthy females participated in the investigation. The older adults were interviewed by telephone to determine eligibility and adhered to inclusion criteria previously outlined [9]. In brief, they had no known musculoskeletal or neurophysiological conditions which could negatively affect balance control during walking. The participants had an uncorrected visual acuity of ≥20/100 and were able to ambulate in the community without visual correction. The participants were also free from convergence insufficiency. Although this is not a typical problem in older adults [20], it could have affected their ability to focus on the stimuli. The investigation was carried out in accordance with the University of Cumbria's recommendations and guidelines for research involving human subjects, and all procedures, information to the participants, and participant consent forms, were approved by the University of Cumbria Research Committee. All participants gave written informed consent in accordance with the Declaration of Helsinki.

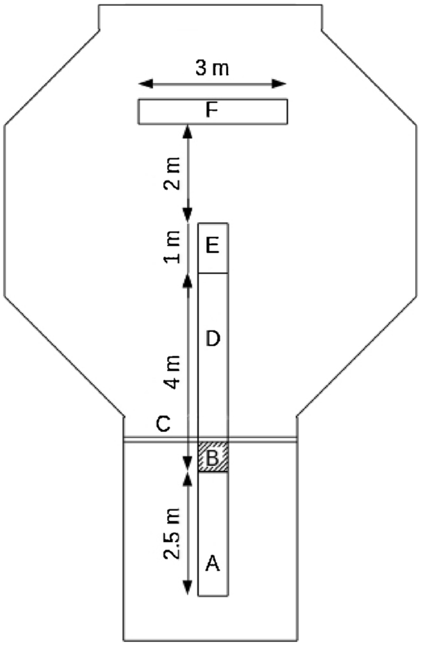

**Fig. 1.** A schematic diagram of the experimental environment. The walkway into the waiting room consists of entry area (A); contact mat (B); sliding doors (C); data collection area (D); exit area (E); actor area (F). All distances are to scale. Note that the observer walkway was not visually marked out and only verbal instructions were given to instruct the participants to stop walking.

### 2.2. Equipment

Testing was carried out on a flat walkway in an everyday use waiting room (Fig. 1). The walkway consisted of a 2.5 m entry area, which has previously been shown as adequate for older adults to reach a steady-state velocity [21], a 4 m data capture area where balance characteristics were assessed, and a 1 m exit area. Sliding doors, controlled by the researcher, concealed the waiting room from the participants when they were at the start of the walkway. A member of the research team (actor) would be absent from or standing or walking within a standardised actor area at the far end of the waiting room (Fig. 2, see experimental protocol). A custom-made contact mat was used to send a signal to a display which informed the actor when to begin walking and in which direction (also see experimental protocol). Four inertial measurement units (IMUs: Opal, APDM, Portland, Oregon) measured accelerations of the centre front head, sacrum, and left and right ankle anatomical land marks of each participant. Participants wore eye tracking glasses (Tobii Glasses 2 Eye Tracker, Tobii Technology, Danderyd, Sweden) which have a one-point calibration procedure, and autoparallax and slippage compensation allowing for persistent calibration throughout each trial.

### 2.3. Experimental protocol

The sliding doors were shut before each trial and then opened signalling the trial to commence. The participants then walked straight into the room at a self-selected pace until verbally instructed to stop when they reached the exit area. Three conditions were implemented: free gaze (FREE), stationary actor (STAT), and walking actor (WALK). For FREE, the waiting room was void of the actor. For STAT, the actor stood stationary in the centre of the participant field of vision. For WALK, on the first heel strike on entering the data capture area, the contact mat (beginning at the start of the data capture area and ending 30 cm along the walkway) sent a signal to a laptop out of view of the participant which informed the actor to walk 1.5 m horizontally across the participant field of vision. The direction was random on each trial.