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Impact of aging on visual reweighting during locomotion

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HIGHLIGHTS

- Young adults can reweight sensory information while walking and are less reliant on visual cues with increased walking speed.
- Older adults have difficulty ignoring irrelevant visual cues when walking and are less adept at sensory re-weighting.
- Age-related changes in sensory-motor control may related to mobility challenges in older adults.

ABSTRACT

Objectives: The purpose of this study was to investigate the ability of young and old subjects to reweight visual cues while walking at normal and fast speeds.
Methods: Ten young (23.49 ± 4.72) and ten older adults (age 76.22 ± 3.11) were asked to physically walk straight while viewing a virtual scene in a head-mounted display (HMD) unit under three conditions: no visual perturbation, blank (no visual input), and visual perturbation. Subjects performed the tasks walking at two speeds: preferred self-pace and fast. Variables calculated included trajectory, heading angle, and body segment orientations.
Results: In the perturbation condition, the older adults walked with higher segmentation and more deviations of the body's centre of mass. Only the young subjects were affected by the walking speed, with an improved performance when walking fast.
Conclusions: Old age affects the ability to re-weight visual information and make postural or locomotor adjustments in real time. The lower errors of the young adults in the fast conditions suggest decreased cortical control of locomotion with increasing speeds.
Significance: Visual information presented in real time can impact on balance and mobility in older adults, and thus should be given serious consideration for the purpose of evaluation and intervention.

1. Introduction

Goal-directed locomotion involves a dynamic interplay between visual, vestibular, and proprioceptive senses, which act in concert with motor outputs to adapt behaviours or tasks to the environment. In order to successfully control walking or any movement for that matter, one must carefully adjust the relative contributions of each sensory input so that more importance is placed on relevant stimuli, and that irrelevant information is ignored, a process known as multisensory reweighting (Horak and Macpherson, 1996). For example, when standing on the platform as a train approaches, one needs to down-regulate visual information so that the visual perturbation caused by the motion of the train does not destabilize one's posture, a common task that healthy young people can perform quickly and effortlessly.

With advancing age, it appears that the reweighting process becomes more challenging (Horak and Macpherson, 1996; Horak et al., 1989). Evidence from postural control studies show that the elderly strongly rely on visual cues for stability and balance. Older adults have much greater sway responses than younger subjects when visual information is suddenly removed (Hay et al., 1996; Teasdale et al., 1991), or when viewing moving scenes (Borger et al., 1999; Bugnariu and Fung, 2007; Simoneau et al., 1999; Sundermier et al., 1996; Wade et al., 1995). However, some have suggested that impairments in the elderly are a function of slower multisensory adaptation rates, since performances significantly improve when older adults are given more time to perform a postural task or to habituate to a moving stimulus (Jeka et al., 2010; O'Connor et al., 2008).

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Few studies have examined aging effects on the contribution of vision to the control of locomotion. Some have shown that under certain conditions involving visual motion, older adults respond similarly to young adults. Chou et al. (2009) reported no aging effects in response to walking with different optic flow speeds and asymmetries in flow patterns. Likewise, we have also shown that older adults respond in a similar manner to younger adults when instructed to walk in a virtual environment with changing directions of rotational optic flow in the yaw direction (Berard et al., 2011). However, these were the few studies that purposely examined the influence of visual cues on locomotion. The Chou study (2009) gave no specific instructions, but rather aimed at observing natural responses to changing visual stimuli, and we expressly asked subjects in our previous study (Berard et al., 2011) to use the visual information to control their walking. Neither of these tasks specifically target age-related changes to sensory reweighting. Therefore, the ability of older adults to reweight sensory information during walking remains to be investigated.

The purpose of this study is to examine the ability of healthy older adults to reweight sensory information during locomotion. More specifically, we aim to compare the abilities between younger and older subjects to down-regulate optic flow cues while walking in a virtual environment at self-pace normal and fast walking speeds. We hypothesize that older adults will have more difficulty ignoring rotating optic flow cues than younger subject when instructed to walk straight in a virtual environment. Because of decreased visuomotor processing time, we expect the older adults to have larger heading errors when gait speed increases.

2. Methods

2.1. Subjects

A convenience sample of ten healthy young subjects (mean age 23.49 ± 4.72 years) and ten healthy older adults (mean age 76.22 ± 3.11 years) participated in the study. All participants in the study were naïve to the experiment and had no prior experience moving in virtual environments. Subjects had corrected-to-normal vision (20/40 or better) and no self-reported musculoskeletal or neurological conditions interfering with locomotion. They were also screened for dizziness using the Dizziness Handicap Inventory (score $\geqslant$24 out of 25) and cognitive deficits (score $\geqslant$27 on the Mini-Mental State Examination). All subjects signed an informed consent form, which was approved by the institutional ethics board.

2.2. Experimental set up

Subjects walked overground in a large open space in the laboratory (12 $\times$ 8 m walking area) while viewing stereoscopically a 3D scene shown in a helmet-mounted display unit (HMD; NVisor with 60° diagonal field of view and 1280 $\times$ 1084 pixels resolution) that they wore. The scene presented in the HMD was that of a room with the same virtual dimensions as the experimental walking area in the laboratory (Fig. 1). Subjects were outfitted with 39 passive reflective markers on anatomical landmarks as defined in the Vicon PlugIn-Gait model. Kinematic data of the head and whole body were captured at 120 Hz with a 12-camera Vicon-512™ system. Movements of the head were tracked in real time via three markers placed on the HMD and used by the CAREN-3 (Computer Assisted Rehabilitation Environments, MOTEK BV) to update the subjects' perceived position and orientation in the virtual scene. This allowed for movements of the head to be synchronized and displayed in the HMD in real time, with a negligible delay of 25 ms.

2.3. Protocol

Subjects were instructed to "walk straight in the physical room or laboratory" (as opposed to the virtual room). They were to physically walk as straight as possible while viewing a scene in the HMD. The experiment consisted of two blocks of trials. Each block of trials was identical except for the instructions for the subject to walk at their 'normal' gait speed, similar to their everyday tempo, or at a 'fast' gait speed such that they were to walk as quickly as they could without jogging or running and still feel stable, as if they were hurrying to catch a bus. The presentation of blocks was randomly assigned so that half the participants experienced the fast walking condition first and the other half began with the normal walking condition. The contents of each block were identical, though the presentation order of the trials within the block was randomly assigned. Within each block the subjects were presented with three conditions: (1) Perturbation: after walking 1.5 m, the focus of expansion (FOE) of the scene in the HMD would gradually rotate to the right or the left about a vertical axis so that the total rotation was 40° to the left or right over the remaining 3.5 m of forward walking (5 m total). The rate of the perturbation was a direct function of the walking velocity of the participant. This perturbation was superimposed onto the movements of the participants. (2) No Perturbation: As the subjects walked forward in the virtual room, no additional movements of the scene were applied, other than those of the participant. (3) Blank: In blank trials, the complete screen was blacked out to create a condition with no visual input. Subjects performed 6 trials per condition for a total

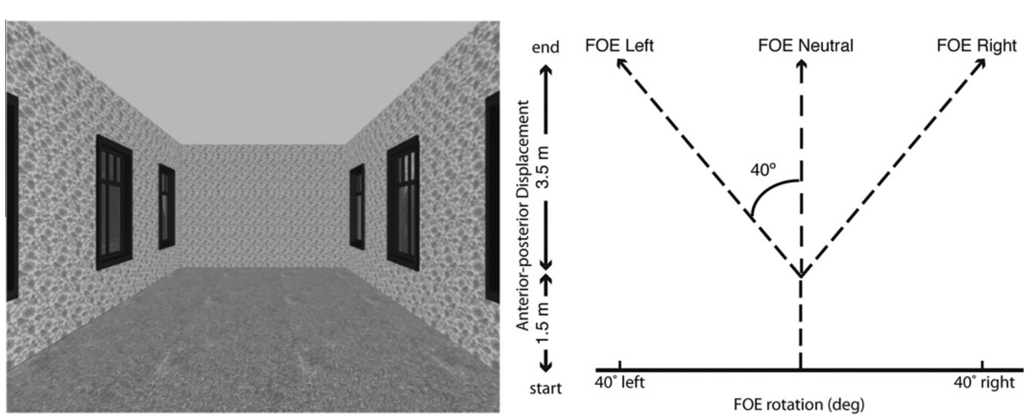

Fig. 1. Left side shows a still image of the virtual scene viewed by participants. On the right is a schematic of the perturbations applied to the movements of the virtual scene.