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Effects of uni- and multimodal cueing on handrail grasping and associated gaze behavior in older adults☆,☆☆

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ABSTRACT

Introduction: It appears that age-related changes in visual attention may impair ability to acquire the visuospatial information needed to grasp a handrail effectively in response to sudden loss of balance. This, in turn, may increase risk of falling. To counter this problem, we developed a proximity-triggered cueing system that provides a visual cue (flashing lights) and/or verbal cue ("attention use the handrail") to attract attention to the handrail. This study examined the effect of handrail cueing on grasping of the rail and associated gaze behavior in a large cohort ($n = 160$) of independent and ambulatory older adults (age 64–80).
Methods: The handrail and cueing system was mounted on a large (2 m × 6 m) motion platform configured to simulate a real-life environment. Subjects performed a daily-life task that required walking to the end of the platform, which was triggered to perturb balance by moving suddenly when they were adjacent to the rail. To prevent adaptation, each subject performed only one trial, and a deception was used to ensure that the perturbation was truly unexpected. Each subject was assigned to one of four cue conditions: visual, verbal, multimodal (visual-plus-verbal) or no cue.
Results: Verbal cueing attracted overt visual attention to the handrail and markedly increased proactive grasping (prior to the onset of the balance perturbation) particularly when delivered unimodally. Subjects were otherwise much more likely to grasp the rail in reaction to the perturbation. A possible trend for visual cueing to improve the accuracy of these reactions was offset by adverse effects on reaction speed and on frequency of proactive grasping.
Conclusions: The results support the viability of using unimodal verbal cueing to reduce fall risk by increasing proactive handrail use. Conversely, they do not strongly support use of visual cueing (either alone or in combination with verbal cueing) and suggest that it may even have adverse effects. Further study is needed to evaluate effects of handrail cueing in a wide range of populations and real-life settings.

1. Introduction

Balance-recovery reactions that involve rapid reaching movements to touch or grasp a handrail for support can play a critical role in preventing falls, particularly in older adults who tend to be more dependent than younger persons in using the arms to respond to sudden loss of balance (Maki and McIlroy, 2005). Volitional reaching movements to grasp or touch an object such as a handrail are often guided by eye movements that lead to fixation of the target in the central visual field (Abrams, 1992; Carnahan and Marteniuk, 1991; Land, 2006). However, for reaching reactions that are triggered by sudden unexpected or unpredictable loss of balance, it appears that the urgent need to react rapidly imposes temporal constraints that preclude use of eye movements to guide the reach, forcing instead a reliance on peripheral vision and/or visuospatial information that has been previously tracked and stored in working memory (Cheng et al., 2012a,b; Ghafouri et al., 2004; King et al., 2009, 2010, 2011).

The need to monitor one's surroundings so as to track the location of objects such as handrails suggests a critical role for the acquisition, processing and storage of visual information, involving

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various aspects of visual attention, gaze control and spatial working memory. All of these aspects of visual processing are known to decline with aging (Kemps and Newson, 2006; Munoz et al., 1998; Salthouse, 1992) and there is evidence that such deficits can impair motor behavior in situations that require visual monitoring of the surroundings. For example, age-related decline in the ability to rapidly extract information from the peripheral visual field predicts increased risk of driving accidents (Owsley et al., 1998), and also correlates with reduced mobility (Owsley and Mcgwin, 2004). In another study, older adults at high risk of falling were found to exhibit different gaze behavior in comparison to low-risk subjects (Chapman and Hollands, 2006), suggesting that the strategy used to gather visuospatial information during walking may affect risk of falling. With regard to handrail grasping behavior, we recently found that older adults were highly dependent on using a handrail to recover balance (in reacting to an unexpected balance perturbation while ambulating in an unfamiliar environment), but commonly failed to direct overt visual attention to the rail (King et al., 2009). In contrast, the majority of young adults fixated on the rail one or more times upon entering the unfamiliar environment (King et al., 2009, 2011).

To help counter age-related problems in acquiring the visuospatial information (VSI) needed to guide effective handrail grasping behavior, we developed a proximity-triggered handrail cueing system that provides a visual cue (flashing lights) and/or verbal cue ("attention, use the handrail") so as to attract attention to the handrail as the person approaches (Scovil et al., 2007). The cueing is intended to automatically draw attention to the handrail, and thereby compensate for age-related deficits in visual attention that might otherwise cause a failure to detect the presence of the handrail or to map its location accurately. In doing so, we anticipated that the cueing would improve ability to rapidly and accurately reach to grasp the handrail for support in response to sudden loss of balance. We also anticipated that the cueing might help to avoid age-related problems in executing effective reach-to-grasp reactions by increasing the tendency to hold the rail proactively, before loss of balance occurs.

To evaluate the effects of the cueing, the handrail system was mounted on a large (2 m × 6 m) motion platform configured to simulate a "real-life" environment, and older-adult subjects performed an activity that required walking to the end of the platform, which was triggered to perturb balance by moving suddenly and unexpectedly when they were adjacent to the rail. A deception was used to ensure that the perturbation was truly unexpected. To prevent adaptation, subjects performed only one trial, which was their very first exposure to the perturbation and environment. Each of 160 subjects was assigned to one of four cueing conditions: (1) no cue, (2) visual cue; (3) verbal cue; or (4) multimodal (visual-plus-verbal) cue. We hypothesized that the primary effect of the visual cueing would be improvement in the speed, accuracy and effectiveness of the perturbation-evoked reach-to-grasp reactions, whereas the primary effect of the verbal cueing would be an increased tendency to hold the rail proactively. In view of evidence that multimodal cueing is more effective than unimodal cueing (Laurienti et al., 2006), we hypothesized that the combination of visual and verbal cueing would enhance both of these benefits. Data from a small subset of the current sample (12 of the no-cue subjects) have been reported previously in a study of age-related differences in handrail grasping behavior (King et al., 2009).

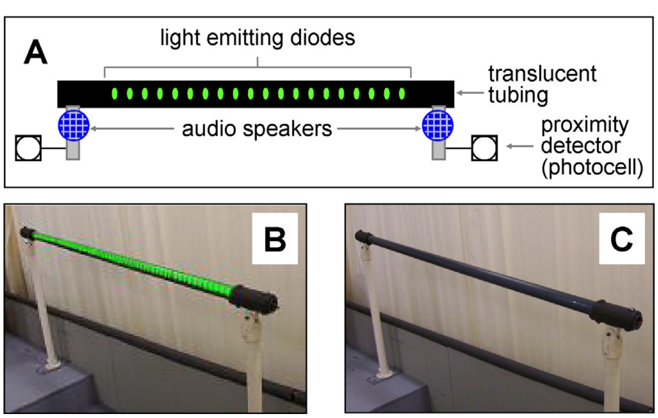

Fig. 1. Conceptual drawing (A) of the handrail cueing system and photographs of the railing portion of the system (B and C). During visual cueing, green light-emitting diodes (LEDs) mounted within the translucent black railing are controlled to suddenly start to flash rapidly on (B) and off (C). During verbal cueing, audio speakers deliver a verbal prompt ("attention, use the handrail"). The proximity sensors (photocells) that trigger the cueing are mounted on the wall near floor level, ~1.5 m from the end of the railing.

Adapted from Scovil et al. (2007).

2. Methods

2.1. Handrail cueing system

The handrail cueing system was developed in accordance with established principles of attentional control and optimal design of warning systems, and has been described in detail elsewhere (Scovil et al., 2007). Briefly, the system comprises: (1) a translucent plastic black railing; (2) a series of green light-emitting diodes (LEDs) mounted inside the railing (along the longitudinal axis); (3) an audio speaker mounted in close proximity to the railing; and (4) a photocell that triggers onset of visual and/or verbal cueing when a person approaches (~2 s before the body is adjacent to the rail); see Fig. 1. For the visual cueing, the photocell triggers the LEDs to suddenly begin to flash at a frequency of 3 Hz, and these continue to flash for an interval of 3 s. For the verbal cueing, the photocell triggers immediate playback of a 1.5 s recorded message ("attention, use the handrail") that is delivered twice in rapid succession in an urgent tone (within an interval of ~3 s) by a female voice (sound level >15 dB above background noise).

2.2. Participants

A cohort of 160 healthy older adults (41 males, 119 females) aged 64–80 (mean age 70, SD 4.6) participated in the study. None had participated in previous balance studies, and all were naïve to the present protocol. Volunteers were recruited via advertisements (placed in local newspapers), posters (placed in stores, churches, apartment buildings and community centers) and word of mouth, and were asked to respond (over the telephone) to questions about their medical history, mobility level and handedness. The recruitment advertisements specified only that we were looking for volunteers potentially interested in participating in a research study and that they should be "65+ years of age, right-handed and generally healthy".

In addition to being right-handed, subjects were required to be able to stand and walk without aid and to understand English instructions. They were excluded from the study if they reported any: (1) neurological disorders; (2) eye disease or visual disorders; (3) vestibular or somatosensory disorders; (4) recurrent dizziness or unsteadiness; (5) use of medications that may affect balance; (6) musculoskeletal disorders or other medical conditions interfering significantly with daily activities; or (7) functional limitations of limb use. Visual acuity was tested in our laboratory, prior to starting the experiment. Subjects were required to have a minimum corrected Snellen visual acuity of 20/40 and were permitted to wear corrective lenses during the experiment. Only three