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# Safety on stairs: Influence of a tread edge highlighter and its position

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ABSTRACT

*Background:* Falls sustained when descending stairs are the leading cause of accidental death in older adults. Highly visible edge highlighters/friction strips (often set back from the tread edge) are sometimes used to improve stair safety, but there is no evidence for the usefulness of either.
*Objective:* To determine whether an edge highlighter and its location relative to the tread edge affect foot placement/clearance and accidental foot contacts when descending stairs.
*Method:* Sixteen older adults (mean ± 1 SD age; 71 ± 7 years) with normal vision (experiment 1) and eight young adults (mean ± 1 SD age; 24 ± 4 years) with visual impairment due to simulated age-related cataract (experiment 2) completed step descent trials during which a high contrast edge highlighter was either not present, placed flush with the tread edge, or set back from the edge by 10 mm or 30 mm. Foot placement/clearance and the number of accidental foot contacts were compared across conditions.
*Results:* In experiment 1, a highlighter set back by 30 mm led to a reduction in final foot placement ($p < 0.001$) and foot clearance ($p < 0.001$) compared to a highlighter placed flush with the tread edge, and the percentage of foot clearances that were less than 5 mm increased from 2% (abutting) to 17% (away30). In experiment 2, a highlighter placed flush with the tread edge led to a decrease in within-subject variability in final foot placement ($p = 0.004$) and horizontal foot clearance ($p = 0.022$), a decrease in descent duration ($p = 0.009$), and a decrease in the number of low clearances (<5 mm, from 8% to 0%) and the number of accidental foot contacts (15% to 3%) when compared to a tread edge with no highlighter present.
*Conclusions:* Changes to foot clearance parameters as a result of highlighter presence and position suggest that stairs with high-contrast edge highlighters positioned flush with the tread edge will improve safety on stairs, particularly for those with age-related visual impairment.



## 1. Introduction

Falls sustained on steps/stairs are the leading cause of accidental death in older adults (Startzell et al., 2000). Non-fatal injuries due to falling on steps (e.g. surface level change or kerb) or stairs are also highly prevalent in older adults, ranging from severe bruising to hip fractures (Gallagher and Scott, 1997; Templer, 1992). In the UK an estimated 11% of injuries sustained in home accidents in 2002 occurred due to a fall on steps/stairs (Department of Trade and Industry, 2002; Roys, 2001). Almost 1000 deaths occur each year in the UK as a consequence of older adults falling on steps or stairs in the home (Hill et al., 2000). Identifying ways to improve safety on stairs is thus a vital public health issue. Falls in older adults are three times more likely to occur during stair descent compared to stair ascent (Cohen et al., 1985; Tinetti et al., 1988), with a higher incidence occurring on either the top or bottom steps (Templer, 1992). Falls also frequently occur when transitioning from one level to another, such as descending a kerb (Gallagher and Scott, 1997). Reduced foot/heel clearances over the tread-edge, greater clearance variability and misjudgements in foot placement when descending steps or stairs are factors that are reported to increase falls risk (Hamel et al., 2005; Jackson and Cohen, 1995; Simoneau et al., 1991).

Vision is known to play a major role in successful stair negotiation (Startzell et al., 2000; Templer, 1992) and visual impairment becomes increasingly likely as people get older (Klaver et al., 1998). Locating the tread edge may be particularly problematic for older adults when the lighting levels are low and/or the step covering is patterned and/or if they are visually impaired (Buckley et al., 2005a,b, 2008; Hamel et al., 2005; Hill et al., 2000; Templer, 1992). To help counter the problems associated with poor vision, building regulations state that a visually contrasting permanent edge highlighter should be placed across the full width of each step-tread to help clearly delineate the tread edge from the rest of the tread (Archea et al., 1979). A tread edge highlighter can also be incorporated as part of the step 'nosing', and the British (building) standards (British Standards Institution, 2009) describe how the nosing should encompass both the front edge portion of a tread and top portion of the step riser. British and American building guidelines state that the width of the nosing on the tread should be between 50 and 65 mm (British Standards Institution, 2009) or no more than 38 mm (Architectural U, 2002) respectively. Slip-resistant

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strips (friction strips) are also commonly used on tread surfaces to help prevent slips and falls. However, there are no standards/guidelines regarding the location of slip-resistant strips, although by definition slip-resistant 'nosings' will be positioned at the tread edge. As slip resistant strips typically provide a visual cue regarding the position of the tread edge, they may be a source of visual ambiguity when positioned away from the tread edge (as is not uncommon on public stairs, Fig. 1a–b).

Previous research, looking at the effects of edge highlighters, has failed to determine any significant changes in stair descent stepping behaviour (Simoneau et al., 1991; Zietz et al., 2011). However, in both studies foot placement/clearance was only reported for the mid-stair portion of a five-step stairway, where trips/falls are least common (Templer, 1992), and where somatosensory information from negotiating the previous steps may have been used to judge riser height instead of relying on accurate visual information (Buckley et al., 2005a; Chapman et al., 2010).

The aims of this study were to determine: i) whether the presence and location of a step-edge highlighter affected foot placement/clearance and the number of accidental foot contacts during descent of a flight of stairs (experiment 1 – habitual vision) and ii) whether the effects would change for those with poor/impaired vision (experiment 2 – cataract simulation).

We chose not to use older participants with age-related visual impairment in experiment 2 for the following reasons: 1) Pilot work indicated that manipulating the position of a step-edge highlighter had a significant and profound effect on stair descent safety, which we thought would make risk of tripping and falling in elderly individuals too great. If we had used elderly participants we would have had to use a safety harness system, but this would have led to an unnatural and/or very cautious stair descent approach. 2) Previous research has indicated that stepping parameters in both young and older adults are affected by blurred vision (due to simulated cataract), but that the effects are similar for both age groups (Heasley et al., 2005). Thus the use of younger participants with visual impairment due to a cataract simulation (Elliott et al., 1996; Heasley et al., 2004, 2005) allowed us to satisfactory meet the study's aims as the effects of blurring vision in young adults were expected to provide data that is representative of how older adults with simulated cataract would have performed.

## 2. Materials and methods

### 2.1. Participants

The average (±1 SD) characteristics of participants for each experiment are presented in Table 1. The tenets of the Declaration of Helsinki were observed and the experiments gained institutional ethical approval. Participants with a history of musculoskeletal or neurological impairment, cardiovascular disorders, vestibular disturbances, a history of falling or significant eye disease as determined by clinical examination were excluded from taking part. All participants recruited for Experiment 1 had normal vision for their age, with binocular visual acuity better than 0.1 logMAR. Participants in experiment 2 wore cataract simulation goggles (Vistech, Stereo Optical Co., Chicago, Illinois) (Elliott et al., 1996; Heasley et al., 2004, 2005) throughout the entire session, which reduced contrast sensitivity (Pelli-Robson chart) to approximately 0.75 log units. This is a level of vision that would be described as visual disability (Leat et al., 1999), which is most common in the elderly population (Elliott et al., 1997). All participants provided written informed consent to take part in the study.

### 2.2. Stair design and apparatus

The stairs used were custom built for the purpose of conducting research within the gait lab environment. Consisting of three steps, the stairs were 1000 mm wide with the top step consisting of a landing area measuring 1500 mm long (Fig. 2a). Each tread/going measured 285 mm and the step risers ranged between 167 and 175 mm. The step treads and risers were painted a uniform grey colour. A handrail was positioned on the right side of the stairs (as viewed during descent), and crash mats were positioned on the left side for safety.

During the experiments a research team member was positioned close to the stairs to aid participants if they lost balance or stumbled during the trial (this did not occur across any of the trials and none of the participants used the handrail at any time).

### 2.3. Tread edge highlighter

For each experiment, repeated trials were undertaken of four experimental tread edge highlighter conditions: 1) no edge highlighter on the tread (plain); 2) a high-contrast black strip 55 mm wide placed flush with the leading edge of the tread (abutting); 3) a high-contrast black strip 55 mm wide placed 10 mm from the leading edge of the tread (away10); and 4) a high-contrast black strip 55 mm wide placed 30 mm from the leading edge of the tread (away30). In both experiments the edge highlighter was present across the top, middle and bottom step edges. The width of the black strip adhered to British (building) standards (British Standards Institution, 2009). The Weber contrast of the strip against the grey tread background was 95% and the laboratory was lit to an ambient illuminance of 400 lx.

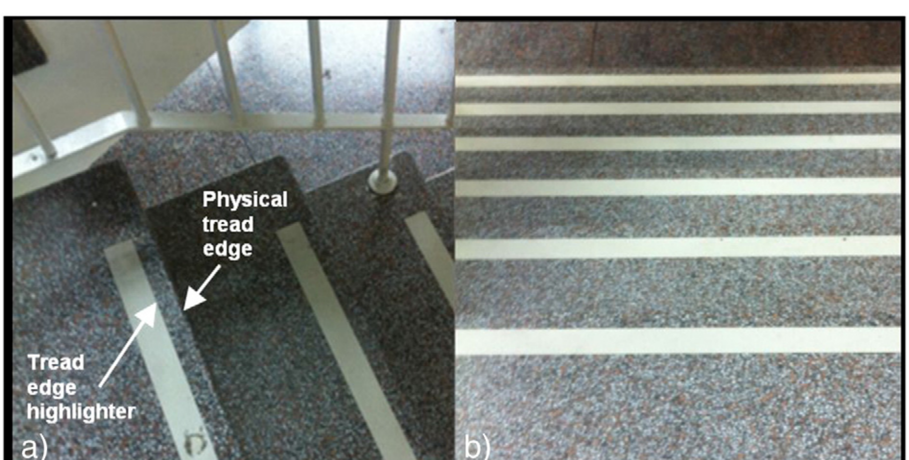


**Fig. 1.** a) The separation (~30 mm) between the slip resistant strip and physical tread edge is noticeable when viewing the public stairs from close up, but from the perspective of the stair user (b) it is difficult to clearly delineate the tread edge from the tread surface on the step below.