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# Lighting for improving balance in older adults with and without risk for falls

SIR—The visual system acquires sensory information about self-position and location of objects in the environment and, together with sensory input from the vestibular and somatosensory systems, helps maintain balance. The dependence on visual information for the maintenance of postural stability and control increases with age due to age-related changes that occur in the vestibular and somatosensory systems [1–10].

Lighting that enhances veridical visual information about the environment for older adults could be a practical and effective intervention to reduce falls risk. Figueiro et al. [11] showed that, in healthy, non-faller older adults, a wall-plug nightlight (NL) was associated with significantly greater sway in the early phase of the sit-to-stand (STS) test than was found with a novel NL system providing low-level ambient illumination and enhanced horizontal and vertical (H/V) visual information.

The present study aimed to extend these findings by testing the effectiveness of a similar NL system on another measure, the weight transfer time (WTT), in two groups of older adults, those with and without fall risks. A longer WTT should be associated with more difficulty in getting up [12–14]. It was hypothesised that compared with wall-plug NLs, WTT in the STS test would be better with the novel NL system for both groups, and that the effect would be larger for fallers than for non-fallers. It was also hypothesised that a high contrast (black on white versus white on white) veridical stimulus would be better for postural stability and control than a low contrast stimulus.

## Subjects and methods

### Participants

Individuals aged 65 or older were recruited for participation in the study ($n = 48$). The Berg Balance Scale (BBS) [15] was used to categorise potential subjects into two experimental groups, those with and without falls risk. Potential subjects who scored 45 or lower on this scale [16–19] and who reported to have fallen at least two times within the past 6 months were categorised as fallers. Please see Appendices 1, 2 and 3 in Supplementary data available in Age and Ageing online for inclusion and exclusion criteria, screening measurement scores and descriptive statistics of participants. All subjects signed approved consent forms from the Institute Review Boards (IRBs) of both Rensselaer Polytechnic Institute and The Sage Colleges.

### Apparatus

Postural stability was assessed using the STS test incorporated into the Balance Master® (NeuroCom International, Inc.), which measures the forces exerted by a subject's feet on a 0.46 m × 1.52 m (18 in. × 60 in.) plate while shifting the body's centre of gravity forward from an initial seated position to an erect standing position. The Balance Master® Report includes four main measures: centre of gravity sway, WTT, left/right symmetry and rising index. Discussed here is the WTT, in seconds (s).

From a distance of 1.5 m (5 ft), subjects viewed a plumb and rigid sheet of cardboard the size of a residential door 2.1 m (7 ft) high and 1.02 m (3.4 ft) wide leaning against a large, uniform white paper screen [2.44 m (8 ft) high × 4. 57 m (15 ft) wide]. The simulated door was black on one side and white on the other so the alternate sides provided two levels of visual contrast (0.94 and 0.06, respectively) against the white screen.

### Lighting conditions

Three lighting conditions were used in the study: (i) a high ambient light level (approximately 650 lux at the cornea) provided by ceiling lights (CL); (ii) low ambient illumination (≤0.015 lux at the cornea) provided by conventional, wall-plug NLs; (iii) low ambient illumination (≤0.015 lux at the cornea) plus robust veridical spatial cues provided by self-luminous H/V lines (Figure 1). Please see Appendix 4 in the Supplementary data available in Age and Ageing online for details on the lighting conditions.

### Procedures

The two groups (fallers versus non-fallers) experienced all three experimental conditions (lighting conditions,

**Figure 1.** Novel nighlighting system concept. Low ambient illumination plus robust veridical spatial cues provided by self-luminous horizontal and vertical lines (H/V condition). Light for the H/V condition was produced by three linear arrays of amber light emitting diodes (LEDs) (LINEARFLEXSIDE; $\lambda_{max} = 615$ nm, OSRAM SYLVANIA). The arrays were positioned behind the top and side edges of the plumb simulated door, mimicking how this novel lighting system might be installed in a residential bedroom. The top array was comprised of 68 LEDs and the two side arrays were each comprised of 140 LEDs. During an STS test subjects could not view the LEDs directly, thus eliminating glare from the bright point sources. Owing to the low light level at the cornea used in the present study, it was not possible to obtain a picture in the actual laboratory setting. This figure was taken from a previous experiment where a similar arrangement was applied.

doorframe contrasts and trial numbers) in a counterbalanced manner. Subjects performed three STS trials under every combination of lighting conditions and doorframe contrast in one session. Subjects adapted to each lighting condition for 20 min before the first trial under the prescribed lighting condition. Both simulated door contrasts were presented to subjects before a change in the lighting condition. An experimental session, including adaptation times, contained 18 trials and lasted approximately 75 min.

Subjects were seated on blocks with their feet parallel on the force plate and were instructed to rise from the blocks as if they would from a chair without arms upon receiving the command to stand. Most subjects placed their hands on their lower thighs to push off while rising from the blocks. The blocks' heights were set at a common chair height of 0.5 m (20 in.) for all subjects in the group of fallers. This height was selected to allow them to stand up without assistance. As part of the between-groups (fallers versus non-fallers) experimental design, a block height of 0.4 m (16 in.) was set for subjects in the non-fallers group, which made the STS test slightly more challenging and, thus, more similar to that facing subjects in the group of fallers.

## Data analyses

A one-between (two groups) and three-within (three lighting conditions × two contrasts × three trials) mixed design analysis of variance (ANOVA) was performed. *Post hoc*, two-tailed, paired Student's *t* tests were used to further examine the main effects and interactions between the independent variables. The criterion probability for a Type I error was set a $P \le 0.05$.

## Results

The ANOVA revealed a significant difference between fallers and non-fallers on the WTT ($F_{1,46} = 30.3$, $P < 0.0001$). The average ± standard error of the means (SEM) was $1.1 \pm 0.09$ for fallers and $0.38 \pm 0.09$ s for non-fallers. There was also a significant main effect of lighting condition ($F_{2,92} = 4.75$, $P = 0.01$). The average ± SEM WTT was $0.67 \pm 0.75$ s under the CL condition, $0.67 \pm 0.057$ s under the H/V condition and $0.84 \pm 0.085$ s under the NL condition (Figure 2). WTT scores were significantly
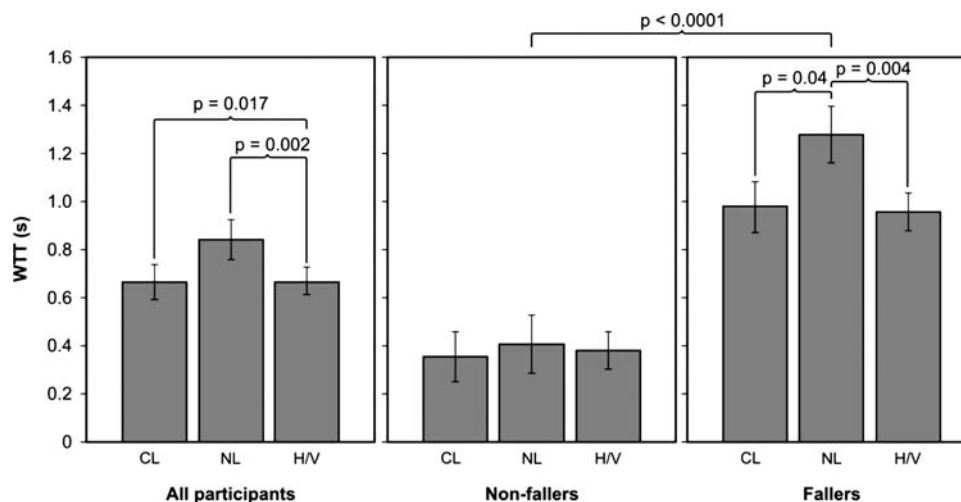


**Figure 2.** Average ± SEM for weight transfer time under the three lighting conditions. Average values for all participants are shown together with those for non-fallers and for fallers.

less when subjects experienced the CL and the H/V conditions than when they experienced the NL condition ($P = 0.017$ and $P = 0.002$, respectively). There was a main effect of trial number ($F_{2,92} = 4.23$, $P = 0.02$). WTT scores in trial 3 were significantly lower than in trial 1 ($P = 0.004$). There was no significant main effect of door contrast ($F_{1,46} = 0.21$, $P = 0.73$) and none of the interactions between the independent variables reached statistical significance.

The groups by lighting conditions interaction almost reached statistical significance ($F_{2,92} = 2.83$; $P = 0.064$); therefore, *post hoc t* tests were performed to examine whether the effectiveness of the H/V condition was greater for fallers than for non-fallers. Fallers had a significantly greater WTT under NL condition than under both the CL ($P = 0.04$) and the H/V ($P = 0.004$) conditions. The average $\pm$ SEM WTT in fallers was $0.98 \pm 0.1$ s under the CL condition, $1.3 \pm 0.1$ s under the NL condition and $0.96 \pm 0.08$ s under the H/V condition.

## Discussion

Extending the findings by Figueiro *et al*. [11], the present results show that WTT under the enhanced NL system were similar to those under high levels of ambient illumination and that these observed lighting effects were greater for fallers than for non-fallers. The simulated door contrast did not have a measurable effect on the WTT, suggesting that simply painting architectural elements in the space may not be as effective as self-luminous enhancements, but this question needs further study.

Falls risk is higher when a person is changing position, such as standing up or sitting down. Based upon the present results and on those by Figueiro *et al*. [11], an enhanced NL that provides *both* low ambient light levels *and* robust veridical visual cues during critical transition times from sitting to standing should be considered for applications in homes and assisted living facilities where falls risk is a concern.

There are some limitations to this study. Although the height of the blocks on which fallers were sitting while performing the STS test was typical of many chair heights, it was still higher than those on which non-fallers were sitting; therefore, the results for non-fallers group may be less realistic than those for fallers because both fallers and non-fallers will likely use similar height chairs in everyday life. These findings are limited to the laboratory environment and need to be replicated in real-life situations and evaluated for acceptability and cost. We expect that the positive impact of this novel nightlighting system will be even stronger than what we measured in the laboratory when older adults are experiencing real-life challenges, such as getting out of bed at night to use the toilet without disrupting sleep by bright ambient lights.

In conclusion, the present results confirm and extend the ones previously published and support the development of enhanced nightlighting solutions that provide robust veridical visual cues to promote better postural stability and control to help prevent falls in the living environments of seniors.

## Key points

- The visual system plays an important role in controlling balance in older adults.
- A nightlighting system providing visual cues and low ambient illumination reduces WTT in older adults.
- Lighting can be used to reduce falls risks in older adults without disrupting sleep.

## Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

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