Light: Towards an Inclusive Perspective

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Light: towards an inclusive perspective

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Abstract. Current research was conducted to gain more insight in how staircase design can contribute in creating a safe and pleasant home environment for older adults. Participants of varying ages (from students to older adults) took part in three studies that combined experimental designs with semi-structured interviews. Renderings of a staircase were created showing different light settings in a nightly situation, from a downward view as well as from an upward view. A mockup staircase with five steps, five different lighting settings and three possible cover materials was custom built. The following specific questions were addressed: 1) which light setting for which cover material can be considered as the most clearly visible and preferred option and 2) what type of additional lighting is best suited at what illuminance level to increase depth perception in stair descent. Guidelines regarding staircase design are formulated by and for (future) interior designers.

Keywords: Staircase Design • Universal Design • Experimental Studies

1. Introduction

In 2050, 4 million Belgians will be older than 60, of which 1.25 million will be over 80 years old [7]. The growing interest in active living and healthy aging [6] entails that older adults prefer to stay as long as possible in their own homes rather than residing in care or retirements facilities [2]. However, to this point housing is generally not well-fit to grow old in [5]. Thus, there is an increasing need for guidelines towards designers for creating age-friendly, safe home environments satisfying older adults' concerns and aspirations [1].

The current research focuses on the staircase as part of the home environment and on rethinking lighting as an aspect defining staircase design [2]. Overall, younger people can better evaluate depth on a staircase and distinguish colors more easily, even in nighttime situations but for elderly people it is not that obvious. Descending a staircase can be a dangerous undertaking: injuries caused by falls on stairs are highly prevalent in the elderly population [4][9][12]. Moreover, in Belgium, 200 deaths per year occur as a consequence of older adults falling on stairs [13]. An adequate contrast between depth and color of the steps is needed in order to create an as safe as possible situation on a staircase. More specifically, it was found that improving lighting to create more visibility on the separate steps, installing (color) contrast on the steps and providing a handrail are home modifications that are particularly useful for older adults [16].

Previous research already indicated that contrast sensitivity is the element that first suffers from age-related changes in people's visual capacities [10][3]. As from the age of 50, our sight weakens and as a result we have difficulty estimating depth. Correctly distinguishing between lighting levels is difficult as from 65 years old. Implementing specific lighting design in the home environment can be a very effective way to compensate for the deteriorating eye sight [14].

Hence, exploring options to improve safety on stairs in a home environment is a public health issue and thus highly relevant. Therefore, the aim of this research is contributing to elderly people's quality of life by studying lighting contrast on stairs in order to create a visually safe environment, especially in a nighttime situation. The ultimate purpose is to distill hands-on guidelines for staircase design.

Three user-focused experimental studies are set up to gain insight in light settings in a staircase design to create a safe and pleasant home environment for elderly.

2. Study 1

2.1 Participants

This explorative study was conducted as part of a student course of the educational programme in Interior Architecture at a Flemish university. Ninety-six participants were recruited via snowball sampling (51 women and 45 men), equally divided over four pre-defined age categories (25-44 years old, 45-64 years old, 65-75 years old and 75+). Per age category 24 participants took part in this experiment.

2.2 Procedure

For this experiment, renderings (i.e. computer graphics) of staircases were created (see Figure 1). That is, the renderings were drawn based on the broad variety of possible

designs taking into account different integrated light settings and different staircase coatings. The renderings were created in Dialux Evo.

The 40 renderings were chosen from a designer's perspective and selected in view of three covering materials – a light wood cover, a dark wood cover and white cover (with the two latter both in a matte and in a glossy finish) and eight light settings on the staircase - lighting above the stair nose; weak lighting under the stair nose; strong lighting under the stair nose; leading light across the steps; 1 spot light in the stair cheek per step; 1 spot light in the stair cheek per two steps; 1 spot light in the stair cheek per three steps; leading light in the handrail). Twenty renderings were made as from the top view and twenty as seen upward from the bottom of the stairs.

Of the 40 renderings each participant was asked to rate and evaluate 10 renderings. The 10 renderings to be assessed were allocated at random, but in such a way that every rendering occurred just as many times. After every rendering shown on the computer screen participants had to fill out a questionnaire with seven statements regarding overall lighting on the staircase, contrast on the steps and the pleasantness of the several lighting setups. The statements were to be rated on a 7-point Likert scale with possible answers ranging from 1 ('I do not agree at all') to 7 ('I totally agree') (e.g. "The staircase is adequately lit").

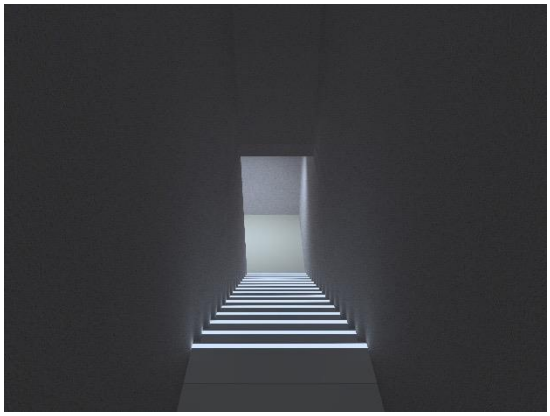

Fig.1. Example of a rendering seen from the top with strong lighting above the stair nose in a white matte finish

2.3 Data analyses and results

Factorability of the seven statements was examined: five of the seven statements correlated with a minimum of $r = .5$ with at least one other statement suggesting reasonable factorability. A principal components analysis with a direct oblimin rotation was conducted on all statements with two factors explaining 73% of the variance.

Internal consistency of the two scales was examined using cronbach's alpha. For the five positively formulated statements cronbach's alpha was quite high, $\alpha = .89$. No substantial increase in alpha was to be found by eliminating items. The two statements

asking about hindering light spots and blinding lighting were, too, highly internally consistent with $\alpha = .69$ [8].

Composite scores were created for the two factors (one factor consisting of positively formulated items and the second factor consisting of negatively formulated items) based on the mean of the items. The rendering of the staircase that scored highest on the positive items ($M = 5.70$, $SD = 0.83$) was a rendering seen from the bottom view, with a white covering and strong lighting under the nose of the stairs. The rendering that received the highest score on the negative items ($M = 4.18$, $SD = 1.81$) was the rendering from the top view, with a white covering and lighting above the stair nose. Overall, the renderings from the bottom view were considered as more positive ($M = 4.53$, $SD = 1.61$) than the renderings from the top view ($M = 3.91$, $SD = 1.64$), with $t(958) = -5.95$, $p < .001$.

The staircase was considered least blinding when finished in a dark wood matte cover ($M = 2.16$, $SD = 1.74$). The light wood cover showed the least blinding spots ($M = 2.74$, $SD = 1.89$) whereas with white glossy finish the staircase was assessed as best lit ($M = 5.22$, $SD = 1.91$), the most clearly visible ($M = 4.58$, $SD = 2.05$) and the lighting was rated as the most agreeable ($M = 4.54$, $SD = 1.90$). The white matte finish ascertained that the steps of the staircase held sufficient contrast ($M = 4.25$, $SD = 2.00$). Overall, respondents rated the lighting of the stair nose as the most pleasant ($M = 2.26$, $SD = 1.36$) and the one spot light per three steps as the most unpleasant ($M = 2.29$, $SD = 1.43$).

When only taking into account respondents of the age categories 65-75 years old and 75+ the rendering that scored highest on being adequately lit, clearest visibility and ideal lighting is the rendering seen from the bottom in a light wood cover with a strong lighting under the stair nose. The rendering that scored the lowest had a dark wood cover in a glossy finish and a weak lighting under the stair nose. The rendering that caused blinding spots and was evaluated as most blinding had a white cover with glossy finish and had lighting of one spot light per step. This rendering was probably rated lowest by the elderly respondents because of insufficient contrast between the steps of the stairs. Renderings holding a leading light across the steps were, too, evaluated negatively and thus were not considered in following studies.

With these results in mind, a second experimental study was set up with a mockup staircase holding five different light settings. Study 2 was performed specifically with elderly participants given they are our main target group.

3. Study 2

3.1 Participants

Respondents for this study were recruited from the open course for seniors at a Flemish university. Over two days, seniors were asked to participate in the experiment. In total, 55 people participated, varying in age from 58 to 81 years old ($M = 67.77$ and $SD = 6.16$).

3.2 Procedure

The mockup staircase that was used in this experiment was custom built for the purpose of conducting research. However, it was never the goal to letting participants ascend or descend the stairs given its unstable structure but rather to allow for the possibility to use it as a sort of shell to be put on existing staircases. This demountable, wooden staircase consists of five steps, each with a rise of 15 cm and a going of 23 cm. A light wooden handrail (6 cm in diameter) was positioned on the right side of the steps (as seen from the top view) and led strips are adjusted at the nose of each step. The test model has five different light settings: a handrail lighting; lighting above the stair nose, lighting under the stair nose, two spot lights in the staircase wall and five spot lights in the staircase wall. In this study it was placed on an actual hallway staircase (see Figure 2) and again a nightly situation was created.

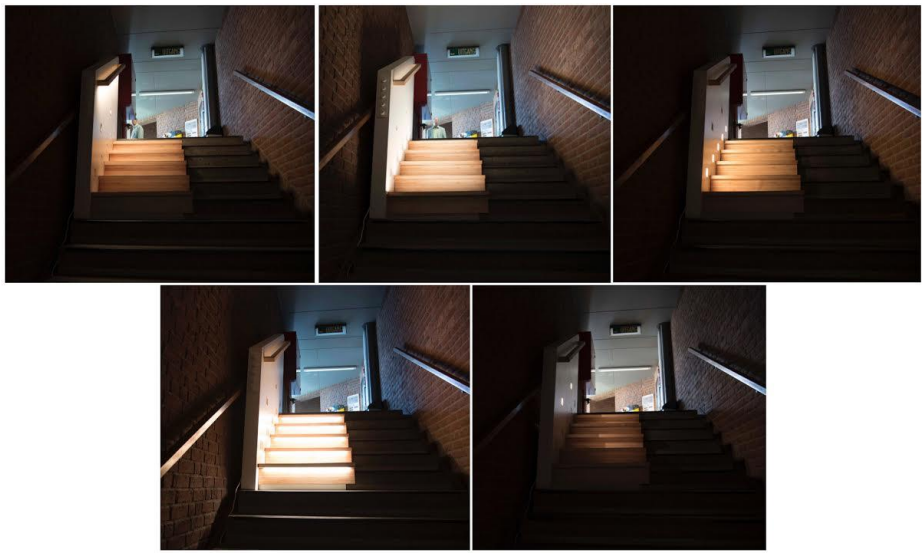

Fig. 2. Test model staircase with a light wood cover and five different light settings.

We used a qualitative approach and planned semi-structured (individual) interviews. On the first day, participants (N = 20) were either asked to evaluate the light settings when looking from the bottom of the staircase upwards or from the top of the staircase downwards. The interviews were organized to elicit the perspectives of the elderly sample on *overall visibility*, on *visibility of the separate steps*, on *visibility of the form of the steps* (the profile), and whether the *lighting was equally distributed*, whether the *lighting was pleasant*, whether the *lighting was blinding* and whether the *lighting was acceptable*. These questions were to be answered for each separate light setting on a 7-point Likert scale with answers ranging from 1 (‘I do not agree at all’) to 7 (‘I fully agree’).

On the second day, participants (N = 35) were asked to answer three questions regarding the light settings on the staircase. In addition, two types of magnetic coverings were used that can be placed over the steps: a light wood cover and a white cover, both in a matte finish. After all, the results of Study 1 showed that the lighter colored covers were preferred over the dark one regarding overall visibility and clear contrast. In addition, the glossy covers were evaluated as blinding.

3.3 Data analysis and results

Overall, the lighting under the stair nose scored highest on overall visibility (M = 6.15, SD = .88), on visibility of the separate steps (M = 5.95, SD = 1.28) and on pleasantness (M = 5.85, SD = 1.46). Differences were found in whether participants had to evaluate the stairs from the top or the bottom view. With regard to the evaluation of the profile of the stairs a significant difference was found between the top and bottom view for the lighting under the stair nose: M_T = 6.60, SD_T = 0.52 vs M_B = 5.11, SD_B = 1.90, F (1, 17) = 5.71, $p < .05$. Similarly, a significant difference was found between the top and bottom view evaluations of the lighting above the stair nose: M_T = 3.64, SD_T = 2.01 vs. M_B = 5.75, SD_B = 1.28, F (1, 17) = 6.76, p = .02.

When taking a look at whether participants find the lighting uniformly distributed a significant difference between top and bottom view was shown for lighting above the stair nose (M_T = 4.30, SD_T = 1.89 vs. M_B = 6.14, SD_B = 0.90, F (1, 18) = 5.67, p = .03.

Lighting under the stair nose was evaluated as most pleasant for the top and the bottom view, although a significant difference is noticed here: M_T = 6.45, SD_T = 0.52 vs. M_B = 5.11, SD_B = 1.90, F (1, 17) = 5.09, p = .04. Both top and bottom view of lighting above the stair nose was considered as the most blinding: M_T = 6.27, SD_T = 1.19 vs. M_B = 3.50, SD_B = 2.67, F (1, 17) = 9.43, p = .007.

From the top view, lighting under the stair nose scored highest on acceptable lighting (M = 5.82, SD = 0.87) whereas from the bottom view lighting in the handrail was better rated on acceptability (M = 5.56, SD = 1.59).

The lighting with two spot lights in the staircase wall was evaluated with the lowest scores on every question, except for pleasantness. The least pleasant setting from the top view was the lighting above the stair nose (M = 2.18, SD = 1.17). The most blinding setting was the lighting above the stair nose (M = 5.11, SD = 2.36), whereas the least blinding was considered the lighting under the stair nose from the top view (M = 1.27, SD = 0.47) and from the bottom view, the handrail lighting (M = 1.88, SD = 1.73). When rating acceptability, from the top view the lighting above the stair nose received the lowest scores (M = 2.64, SD = 1.36).

When covered with the light wood magnetic strip the lighting under the stair nose was rated as the light setting on which the separate steps are clearest visible (48.3%). This was different for the white cover: participants indicated the handrail lighting to be the setting on which the separate steps were clearest visible. 74.3% of the participants indicated that the lighting above the nose was most blinding for both cover materials. With the light wooden cover material, the handrail lighting and the lighting under the stair nose were preferred.

In order to address the problem of depth perception and contrast on stairs in elderly with future designers, students of the faculty of architecture and arts were asked to participate in Study 3.

4. Study 3

4.1 Participants

Twenty-four participants (5 female and 19 male students, aged between 18 and 25 years old) enrolled in an interior and architectural design educational programme in Flanders, Belgium took part in this experimental study.

4.2 Procedure

A qualitative approach using semi-structured individual interviews was used to elicit participants' perspectives on preferred light settings and staircase cover materials in a nightly (half dark) situation. They were also asked to give advice from a designer's point of view on staircase design with young adults as well as elderly people in mind.

For this experiment the staircase test model was used again but contrary to Study 2 it was placed in a laboratory setting: a controlled environment with no other people passing by or interrupting the experiment. Magnetic coverings were placed over the steps: the strips are produced in a light wood structure, a dark wood structure and in a white coating, all in a matte finish (see Figure 3).

Fig. 3. All light settings with a light wood, dark wood and white cover.

Participants were asked to stand on a table (at the same height as the highest step of the stairs) and to look down, as if they were to descend the staircase. From a top view they then evaluated several combinations of cover materials and light settings on the staircase. Three settings were tested: lighting above the stair nose as a point of reference (remained unchanged for all further measurements) and two additional light settings, i.e. lighting under the stair nose and a handrail lighting. All measurements were repeated twice and results were based on the average of both measurements.

In addition, participants were asked – from their expert perspective as future interior architects – to indicate the most suitable combination of lighting and staircase cover material for both young adults and elderly people in a nightly situation. They had to specify at what point the illuminance level was adequately fit, according to them, so as the steps of the staircase were sufficiently lit and did not hinder depth perception. Participants were given one minute to adapt to the nightly situation before the actual evaluation began [11].

The experiment leader controlled the lighting by adjusting the light switch dimmers. A flexible ruler – adhered to the dimmers - contained markers (see Figure 4) in order to be able to correctly measure the illuminance levels with a calibrated illuminance measuring device afterwards.

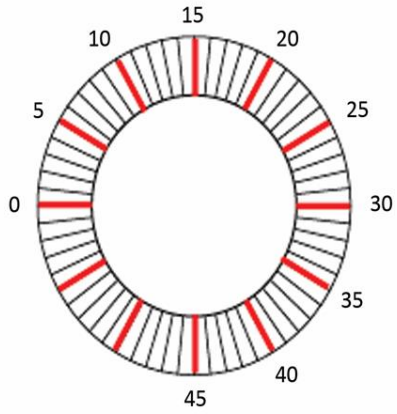

Fig. 4. Flexible ruler with scale display.

From the perspective of accessibility, stair nosing needs to have sufficient contrast with the steps of the staircase. Lighting above the stair nose is perceived as blinding and decreases depth perception but does indicate the position of the stair nose. Therefore, the goal of this study was to examine at what point and with what type of supplemental lighting this initial unwanted state would turn into a situation perceived as well-lit and safe. Hence, illuminance levels were decreased until they no longer were perceived as blinding and then supplemented with handrail lighting or lighting under the stair nose as to increase depth perception.

As mentioned before, participants were to evaluate the setting from the top view. As resulted from the previous studies, the top view gives the most problems with depth

perception. Previous research already showed that falls on staircases in elderly people are three times more likely to occur when descending than ascending the stairs [9]. Hence, it was interesting to test this exact setting (lighting above the stair nose as seen from the top of the staircase) and test how this situation could be improved.

4.3 Data analysis and results

Overall, it seems that the referral scale display level (the basis lighting above the stair nose) remained reasonably constant over all cover materials: the light wood cover (M_{LW} = 17.44), the dark wood cover (M_{DW} = 18.56) and the white cover (M_{W}= 18.06). This scale display was used as the reference point: the experiment leader also measured the scale display when adding extra lighting (i.e. adding lighting under the stair nose or adding handrail lighting). These three different settings were tested to find out whether adding extra lighting would help participants to have a better depth perception.

When adding the handrail lighting to the lighting above the stair nose following measures were registered: M_{LW} = 19.29 (min. = 9 to max. = 30); M_{DW} = 20.44 (min. = 10 to max. = 36) and M_{WH} = 18.58 (min. = 12 to max. = 34). When the lighting under the stair nose was added to the lighting above the stair nose following scale displays were observed: M_{LW} = 20.90 (min. = 6 to max. = 32); M_{DW} = 20.88 (min. = 7 to max. = 36) and M_{WH} = 18.44 (min. = 6 to max. = 29).

The dark wood cover requires a higher illuminance level than the light wood and white cover when adding handrail lighting to the basis lighting above the stair nose. Apparently, depth perception is reduced when stairs carry a darker color. This result corroborates the findings of Study 1 where the renderings in a dark wood finish were also rated as the least clearly visible. The illuminance levels of the added lighting under the stair nose is similarly high in both wood cover finishes. When finished in the white cover the lighting under the stair nose requires the lowest illuminance level.

We also found a significant correlation between the illuminance levels of the sole lighting above the stair nose and the extra lighting in both handrail and lighting under the stair nose. Overall, the brighter respondents need the basis lighting – the lighting above the stair nose – the brighter they need the added lighting to be, with a significance level of $p < .001$ for all combinations of cover materials and light settings. More specifically, when only taking into account those respondents that already indicated being in need of a high illuminance level for the lighting above the stair nose (a high level is considered here as a level above average) analyses show that for the light wood cover a significant correlation can be found between the lighting above the stair nose and the extra handrail lighting, r (11) = .82, p = .002. When only considering respondents that needed an above average illuminance level for the lighting above the stair nose in a dark wood finish, a marginally significant correlation was found between the lighting above the stair nose and the handrail lighting, r (10) = .63, p = .05. A significant correlation was also found between the lighting above the stair nose and the lighting under the stair nose, r (10) = .69, p = .03. Results from respondents indicating the need for an above average illuminance level for the white cover show significant correlations between both lighting above the stair nose and the added handrail lighting, r (11) = .66, p = .03 and the lighting above the stair nose and the added lighting under the stair nose, r (11) = .83, p = .002.

Participants found all combinations of light settings and cover materials suitable for young adults. For the elderly people the majority of the participants (n = 18) agreed upon the lighting under the stair nose accompanied by the handrail lighting as most suitable for a nightly situation. In addition, the light wood cover material in combination with the aforementioned light setting was preferred and perceived as most clearly visible with regard to depth perception.

5. Conclusions

Results from Study 1 showed that, for the age groups of 65-75 years old and 75+, the renderings that were scored as best lit, most clearly visible and evaluated as with most ideal lighting were seen as from the bottom view and had a strong lighting under the stair nose. The cover material evaluated as the most clear and the least blinding was the light wood cover. The renderings with overall negative assessments had a dark wood material and a weak lighting under the stair nose. The renderings with 1 spot light per step and a white, glossy finish were indicated as the most blinding. As already mentioned, this could be the consequence of elderly people not having sufficient contrast between the steps of the staircase. The most important conclusions that can be drawn from the results of Study 2 are that seen from a top view, lighting under the nose is preferred and for a bottom view the handrail lighting is preferred. When the steps carry a light wood cover participants indicated the lighting under the nose in combination with the handrail lighting as the most clearly visible and thus was indicated as preferred. Participants agreed upon that the lighting above the stair nose was the most blinding. Study 3 indicated that the dark wood cover material needed a higher level of illuminance than the lighter colored coverings in order to have sufficient contrast and depth perception. The white cover required the lowest illuminance level. Results also show that the higher participants wanted the basis illumination level, the higher they needed the illuminance level to be of the two additional light settings. Additionally, the students (potential future interior designers) suggested to use lighting under the stair nose in combination with handrail lightings when formulating home adjustment guidelines on stair design for elderly people.

The goal of this research was to get more insight in how safety of a home environment could improve through intelligent stair design: what type of light setting at what illuminance level and what cover material are best fit to create a safe staircase situation for elderly in a nightly setting. As this research was conducted together with students in interior architecture the results are relevant in a context of education and provide opportunities to rethink staircase design for future interior architects.

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