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Affective ambiances created with lighting for older people

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Current lighting technologies provide huge flexibility in creating ambiances that may be adapted to the needs of an occupant in a room. These ambiances not only satisfy visual needs, but may also improve people's well-being. This paper describes one possible application of adaptable light ambiances, namely to counteract negative mood states that older people often experience in care centres. To this end, we wanted to create a pleasant, relaxing ambiance to counteract anxiousness and a pleasant, activating ambiance to counteract sadness. We asked 15 (relatively young) lighting designers to create these ambiances and averaged their input to create both ambiances in a real room. Subsequently, these ambiances were evaluated with the Atmosphere questionnaire by younger and older participants. The affective connotation of the ambiances in terms of the Atmosphere dimensions was well recognized by the younger participants but significantly less so by the older people. Hence, a photo interview with older people was used to make the ambiances more appropriate for them. A final validation experiment confirmed that the affective connotation of these new ambiances was well recognized by the older people.

1. Introduction

LED technology has broadened the playing field in lighting design. As LEDs may be varied in colour and intensity over a large range almost instantaneously, they enable huge flexibility in creating light ambiances. As a consequence, LEDs have contributed to a general shift in focus in lighting design from ambiances that cover visual needs with some accent on decorative lighting towards ambiances that are fully tuneable to people's well-

being. This well-being may be addressed at the biological and/or psychological level. From the biological point of view the impact of mainly blue light has received great interest in the last decade, due to the discovery of a third photoreceptor in the retina.^{1–3} This photoreceptor is responsible for synchronizing the circadian rhythm to the 24-hour light/dark cycle by controlling the release of the hormone melatonin. As a result, it has been shown that bright (blue) light increases alertness during the night,⁴ improves sleep quality,⁵ may significantly reduce the symptoms of depression for people with seasonal mood disorders,⁶ and even for people with non-seasonal affective

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disorders,⁷ and may positively impact the treatment of patients with dementia.⁸ Although these biological effects of light are very important for the target group of our research, i.e. older people in care centres, we nonetheless mainly focus on the impact that light may have on the psychological well-being of people in our current study.

To what extent light may affect our emotional well-being depends on the factors illuminance and correlated colour temperature (CCT), amongst others, and has an interaction with gender.^{9–12} For instance, McCloughan *et al.*¹² found that anxiety and hostility scores showed complex interactions with illuminance, CCT and gender. Knez⁹ reported that females' negative mood decreased while working under warm white light conditions (i.e. 3000 K) and increased under cool white light conditions (i.e. 4000 K), while an opposite effect was found for males. However, in a later study Knez and Enmarker¹⁰ found an opposite result; females' negative mood was higher under warm white light conditions (i.e. 3000 K) compared to under cool white light conditions (i.e. 4000 K), while males showed the reverse.

The literature also contains studies on the psychological effects of colour (e.g. coloured walls) on mood, suggesting that the right amount of coloured ambient light may contribute to improve people's mood. Küller *et al.*¹³ found that office workers who judged their offices as colourful experienced a better mood throughout the year than office workers who judged their offices as neutral or colourless. In addition, the colour blue is often referred to as calming (recalling to the blue sky or sea),¹⁴ while the colour red is associated with arousal (reminding us of red alerts and red stop signs).¹⁵ As such, there seems to be a conflicting impact of blue light on the psychological (i.e. calming) and biological (i.e. increasing alertness) levels.¹⁶ However, despite the biological effect, earlier studies agree that red light is more arousing

than blue light,^{17–20} indicating the strong psychological impact of coloured light.

Obviously, deeper knowledge on the impact of coloured lighting on mood is still needed to be able to design intelligent lighting solutions that effectively improve the mood of people. Having this knowledge would, in turn, be of great relevance for a number of contexts and applications, such as in offices, classrooms, hospital rooms and day care facilities. Our research focuses on creating intelligent lighting solutions for care centres for older people, where negative mood states are often experienced, especially at the moment of relocation.²¹ At that moment, older people often experience anxiety and disorientation, because they are in new surroundings and because they know that they are in the last stage of their life. As well, they may be sad and depressed because they miss their home, family, friends and pets.²² Reducing these negative feelings with a positive ambience in the room may improve their quality of life and reduce their demands on the nursing staff.

To this end, we aim at designing pleasant affective ambiences, using the psychological effects of (coloured) lighting. To evaluate the perception of these ambiences, we rely on the concept of atmosphere.²³ Atmosphere does not represent the affective state of a person, but rather the affective state of an environment, and is known to be almost immediately recognized.^{23,24} Vogels²³ quantified perceived atmosphere of an illuminated room as a four-dimensional affective space, consisting of the dimensions, cosiness, liveliness, tenseness and detachment. Based on these findings, Vogels also developed a validated questionnaire to measure perceived atmosphere. Using this measurement tool, various studies have revealed large and consistent effects of lighting on perceived atmosphere.^{25,26} Vogels *et al.*²⁶ revealed that warm white light (2800 K) was perceived as more 'cosy' and less 'tense' as compared to cold white light

(6000 K). In addition, increasing the illuminance (from 40 lx to 400 lx) resulted in a less 'tense', less 'cosy' and more 'lively' atmosphere. Custers *et al.*²⁵ found a negative relation between brightness and 'cosiness'. From these findings we may conclude that systematic changes in light characteristics influence the atmosphere, and so, the affective experience of the room.

On the longer term, perceived atmosphere is expected to change the emotional state of a person in the room in the direction of that same affective state. The main argument for this assumption is that mood is generally quantified in a two-dimensional affective space, with the bipolar axes being pleasantness and arousal.²⁷ Russell and Prat²⁴ used the same bipolar axes to quantify the affective meaning attributed to places. Also the four-dimensional atmosphere model of Vogels seems to be related to the generally used two-dimensional affective space. The dimensions of cosiness and tenseness of the four-dimensional atmosphere model have a link with the pleasantness dimension of mood. Similarly, the dimension of liveliness of the atmosphere model has a relation with the arousal dimension of mood. For instance, being excited is a high arousal, pleasant mood state, while similarly an 'exciting' ambience is a high arousal (i.e. lively), pleasant atmosphere. Hence, because of these underlying relationships we believe that ambiances with a recognized, positive atmosphere may, to some extent, drive the occupant's mood towards the same affective direction.

It is important to notice that the majority of studies on atmosphere perception have been performed with (relatively) young people (18 to 35 years), and so, do not take into account ageing effects in the visual system that may influence the perception of the ambience, or differences in connotation between colour(ed light) and atmosphere that may differ with age. With respect to the visual system, it is known that increased lens

absorption and reduction of the pupil size in the ageing eye result in a decline in absolute sensitivity to light by a factor three over the course of a lifetime.²⁸ Also colour perception is affected by age; the sensitivity of the human eye to short wavelengths (blue) declines, caused by a yellowing of the lens and the selective loss of short-wavelength sensitive cones.²⁸ In line with these age-related visual impairments, Knez and Kers²⁹ found that older people judge an illuminated room as less bright and warmer compared to younger people. But also connotations may change with age. Knez and Kers²⁹ also found that older participants preserved their negative mood better under cooler white light (4000 K) compared to warmer white light (3000 K), while for younger people a reverse effect was found. They argue that different age groups share different conceptions about the meaning of lighting. Yildirim *et al.*³⁰ revealed that older customers were more negative towards coloured interiors. Finally, colour preference significantly differed between age groups, with a preference for blue³¹ and dark colours decreasing with age.³² As a result of these ageing effects, existing knowledge on atmosphere perception may be only partially applicable to older people.

As stated earlier, the goal of this research is to create pleasant affective ambiances for older people. More specifically, we want to create a pleasant high arousing – i.e. activating – atmosphere and a pleasant low arousing – i.e. relaxing – atmosphere for older people, to counteract negative feelings of sadness and anxiety, respectively. As a starting point, pleasant atmospheres were created for younger people based on the input of lighting designers. These ambiances were then validated using Vogels' Atmosphere questionnaire²³ by younger people. Thereafter, a group of older participants also evaluated the same ambiances with the same methodology. In addition, to confirm the relation between the four Atmosphere dimensions of

Vogels²³ and the two affective dimensions of Russell and Pratt,²⁴ we asked the older people to also score the ambiances with the latter questionnaire. As the experimental data revealed significant differences between the atmospheres perceived by younger people and older people, adjustments were needed in the ambience design to reach our goal for the older people. The last part of the paper describes these adjustments and the validation of the adjusted ambiances by older people.

2. Affective ambience design

Fifteen professional lighting designers were asked to provide information on how they would design four specific affective ambiances having a young population in mind. Two ambiances were intended to be high arousal, pleasant ambiances, i.e. ‘activating’ and ‘exciting’, and two to be low arousal, pleasant ambiances, i.e. ‘cosy’ and ‘relaxing’. Their input was collected with a questionnaire specifically developed for this occasion.³³ This questionnaire asked information on the lighting characteristics needed to design each of the four affective ambiances (i.e. ‘activating’, ‘exciting’, ‘cosy’ and ‘relaxing’). More specifically, designers were asked to indicate

settings for (1) general white light, (2) accent white light and (3) accent coloured light. With respect to the general white light, questions were related to CCT, averaged illuminance on the horizontal plane and vertical plane, and dynamics of brightness and CCT. Questions regarding the accent white lighting related to illuminance, CCT, beam angle, beam characteristics and the dynamics of these characteristics. For the accent coloured lighting, the lighting designers had to indicate which colour(s) they preferred for each ambience. For each preferred colour they answered questions related to its illuminance, saturation, beam angle, beam characteristics and the dynamics of these characteristics. The results of the questionnaire revealed that the lighting designers were consistent between each other with regard to the preferred light characteristics for the four ambiances. Apparently, they all used the same underlying design principles to create a given ambience in the room. As such, the input of the lighting designers was averaged resulting in the lighting characteristics displayed in Table 1 for the general and accent white lighting. Table 2 summarizes the hues selected by most lighting designers for each ambience (based on analysing the mode of the answers) and the corresponding (averaged) saturation level, beam angle and

Table 1 Light characteristics for the white general and accent lighting. Values averaged over the 15 lighting designers are displayed together with the standard deviations in brackets

Atmospheres	CCT (K)		Illuminance (lx)			Beam characteristics accent		
	General	Accent	General horizontal plane	General vertical plane	Accent	Angle (°)	K1 = sharp K5 = soft	Dynamics
Cosy	2800 (130)	2700 (45)	125 (35)	165 (40)	260 (55)	30 (8)	3.4 (0.35)	Static
Activating	4050 (945)	3600 (720)	450 (115)	335 (80)	485 (110)	26 (7)	2.2 (0.55)	Slow changes in illumination and CCT
Relaxing	2850 (135)	2750 (55)	175 (70)	145 (70)	175 (75)	35 (10)	3.5 (0.3)	Slow changes in intensity of the spots
Exciting	3700 (955)	3490 (950)	220 (60)	225 (50)	410 (125)	15 (5)	2.8 (0.9)	Fast changes in intensity of the spots

dynamics. Almost all lighting designers preferred to have no dynamics in the ‘cosy’ ambience. For the activating ambience most lighting designers preferred slow dynamics (i.e. with changes over minutes or hours) in the general lighting (so, for the illuminance and CCT). For the relaxing atmosphere, static lighting was preferred; only slow (with changes over minutes) dynamics were suggested in the intensity of the spotlights. Finally, for the exciting atmosphere most lighting designers preferred to have fast changes (i.e. in a time frame of seconds) in the intensity of the spotlights and in the colours of the accent lighting. More details on the process of creating the ambiances can be found in Seuntiëns and Vogels.³³

2.1. Experimental room

The affective ambiances, as described in Tables 1 and 2, were implemented in an experimental room at the Philips Experience Lab. The room has a size of 6 m × 4 m × 3 m, with white coloured walls and an off-white (i.e. ivory white) ceiling. The floor consisted of dark grey carpet tiles. The windows were sealed from the outside in order to prevent any influence of natural light during the experiments. On the inside, the windows were covered with low chromatic curtains. The room was furnished as a living room with a black coffee table, a white sofa and a white chair in its centre. Underneath the coffee table

an off-white carpet was placed, while a black television cabinet with a black 42" television on it was placed near the wall facing the sofa. Finally, a black dinner table with four chairs was placed against the wall on the left-hand side of the sofa.

An overview of the positions of the installed luminaires is shown in Figure 1. Functional white lighting was provided by two cylindrical floor lights consisting of four fluorescent lamps: two lamps with a warm white CCT of 2700 K (Philips Master TL5 HE 28 W/827) and two lamps with a cold white CCT of 6500 K (Philips Master TL5 HE 28 W/865 lamps). Accent white lighting was provided by six pairs of halogen spot lights; each pair consisted of one spot with a warm white CCT of 3000 K (Philips HR Dichroic 50 W GU5.3 12 V 36D) and one spot with a cool white CCT of 4700 K (Philips Diamondline 50 W GU5.3 12 V 36D 1CT).

Decorative lighting was provided by three Philips Living Colour lamps. Two were placed on each side of the television cabinet and one in the upper left corner. A table light consisting of red, green and blue LED strips was mounted underneath the coffee table and illuminated the floor locally. Finally, a Gemini table lamp, consisting of red, green and blue LEDs illuminated the ceiling above the dinner table. Figure 2 shows the four ambiances that were created reflecting a ‘cosy’, ‘relaxing’, ‘activating’ and ‘exciting’ ambience.

Table 2 Light characteristics for the coloured accent lighting

Atmospheres	Colours	Saturation level	Beam angles (°)	Dynamics
Cosy	Orange, blue	Medium	50	Static
Activating	Cyan, blue	Medium	50	Static
Relaxing	Green, blue	Medium	50	Static
Exciting	All colours	High	10, 60	Random

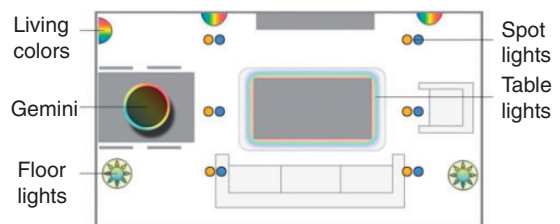


Figure 1 An overview of the positions of the installed luminaires in the experimental room

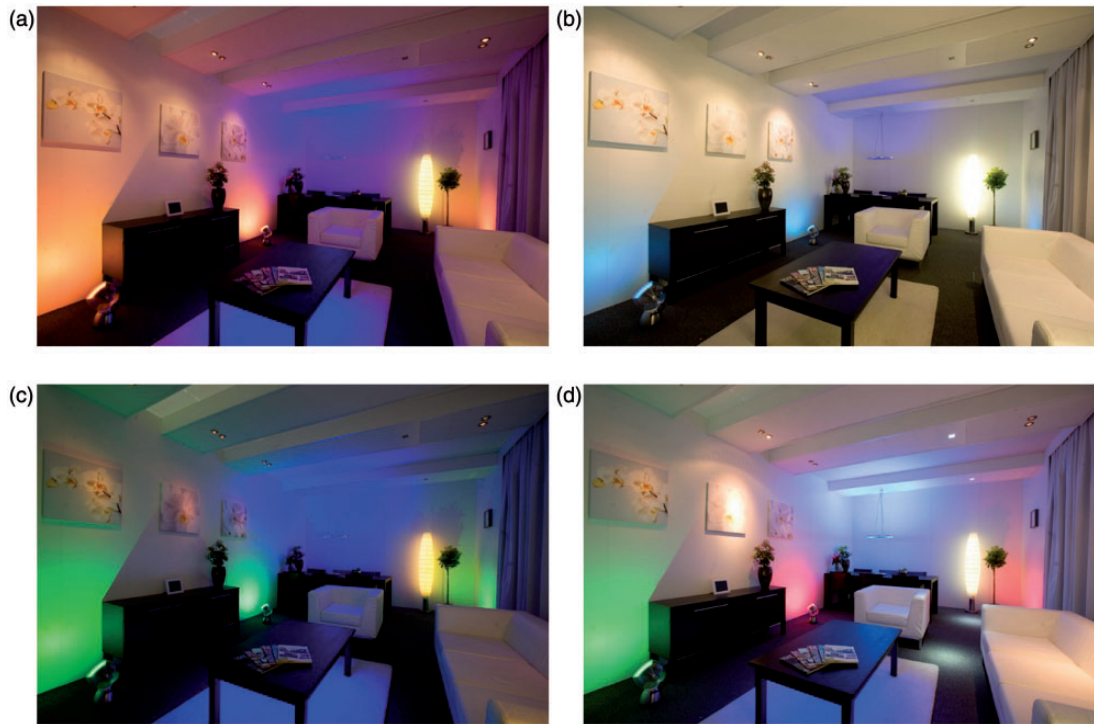


Figure 2 An impression of the ambiances created with the input of lighting designers; reflecting (a) ‘cosy’, (b) ‘activating’, (c) ‘relaxing’ and (d) ‘exciting’ ambiances. (Available in colour in online version)

3. Experiment 1: Recognition of the affective meaning of the ambiances

To investigate how well the four ambiances created (i.e. ‘cosy’, ‘activating’, ‘relaxing’ and ‘exciting’) were recognized, we performed two separate sessions in this first experiment: one with younger participants and one with older people. As the ambiances were created with younger people in mind, we wanted to evaluate to what extent this population recognized the intended affective meaning of the ambiances using the Atmosphere questionnaire of Vogels.²³ In the second session, we measured whether the older participants identified the intended affective meaning of the ambiances, also using the Atmosphere questionnaire. In addition, we asked older people to score the ambiances in terms of pleasure and arousal

with the questionnaire developed by Russell and Pratt.²⁴

3.1. Experimental design

Both experimental sessions used the same within-subject design with the four ambiances being the independent variable and the scores on the four dimensions of perceived atmosphere being the dependent variables. As the older people were also requested to score the pleasure and arousal dimensions of the ambiances, these were two additional dependent variables, only used in a separate analysis.

3.2. Participants

Fifteen young people, aged between 19 and 30 years ($M = 23.8$ years, $SD = 3.1$), participated in the first experimental session (eight females and seven males). In the second

experimental session, 21 older people participated (12 females and nine males), aged between 65 and 88 years ($M=77.2$ years, $SD=6.6$). All participants were native Dutch speakers and they didn't suffer from colour blindness as tested with the Ishihara Colour Test.

3.3. Ambiances

Table 3 depicts the overall light characteristics of the four ambiances, measured as vertical illuminance and CCT at the eye position. For the young people some dynamics were applied in the ambiances: slow dynamics (with changes over minutes) in CCT in the 'activating' ambience, slow dynamics in intensity of the spots in the 'relaxing' ambience and fast dynamics (with changes over seconds) in the intensity of the spots and colours in the 'exciting' ambience. For the older people all ambiances were static, basically because practical evidence has taught us that repetitive dynamics are not really appreciated for longer term use, especially not by older participants.

3.4. Measurement methods

Perceived atmosphere was measured with the shorter version of the Atmosphere questionnaire, developed by Vogels.²³ It contained 12 atmosphere items (see Table 4), where each item had to be scored on a seven-point Likert scale, ranging from totally not applicable (-3) to totally applicable (3). Scores on the three items per Atmosphere dimension were

Table 3 Light characteristics of the four ambiances based on the input of lighting designers, and of the neutral ambience; vertical illuminance and correlated colour temperature were measured at the eye position

Ambience	Illuminance (lx)	CCT (K)	Hue pairs
Cosy	80	2700	Orange, blue
Activating	240	4000	Cyan, blue
Relaxing	60	2700	Green, blue
Exciting	200	4000	Random colours
Neutral	150	3400	Only white

averaged into an Atmosphere dimension score. These scores were subsequently used in the statistical analysis of the data as dependent variables. Beside the Atmosphere questionnaire, the older participants also scored the ambiances with the Affective quality questionnaire of Russell and Pratt.²⁴ The pleasant-unpleasant and arousing-sleepy dimensions of this questionnaire were measured each with 10 different items. Each item had to be scored on an eight-point Likert scale, ranging from extremely inaccurate (1) to extremely accurate (8). Scores on the 10 items were averaged into one pleasure and one arousal score, which we used as dependent variables in the statistical analyses.

3.5. Procedure

Our participants were individually immersed in the ambience and then asked to fill in the questionnaire(s). Questionnaires were fully in the Dutch language and participants were asked to base their scores on the ambience of the complete room. The ambiances were shown for as long as it took the participants to rate them. The order of the ambiances was randomized between participants. While switching between the ambiances, a neutral ambience was shown for 30 seconds. The neutral ambience only consisted of functional white lighting with a neutral CCT (3400 K) and intermediate illuminance (150 lx).

3.6. Results

The inter-rater reliabilities were determined by computing Cronbach's alpha for each

Table 4 Selected atmosphere words for the four atmosphere dimensions, translated from Dutch

Cosiness	Liveliness	Tenseness	Detachment
Cosy	Lively	Terrifying	Formal
Safe	Inspiring	Threatening	Chilly
Intimate	Stimulating	Tense	Business

questionnaire dimension and are summarized in Table 5. For both groups of participants we obtained acceptable to good reliabilities. In general, we obtained the lowest values for the detachment dimension of the Atmosphere questionnaire, but this may be explained by the fact that this dimension was not explicitly addressed in the four ambiances that were created.

Figure 3 presents the averaged scores of the four Atmosphere dimensions for both the younger people and the older people,

Table 5 Inter-rater reliabilities (Cronbach’s alpha) for the four dimensions of the Atmosphere questionnaire and for the pleasure and arousal dimensions of the Affective quality attributed to places questionnaire

		Cronbach’s alpha	
	Questionnaire dimension	Younger people	Older people
Atmosphere questionnaire ²³	Cosiness	0.894	0.905
	Liveliness	0.817	0.745
	Tenseness	0.830	0.845
	Detachment	0.745	0.652
Affective quality questionnaire ²⁴	Pleasure		0.930
	Arousal		0.700

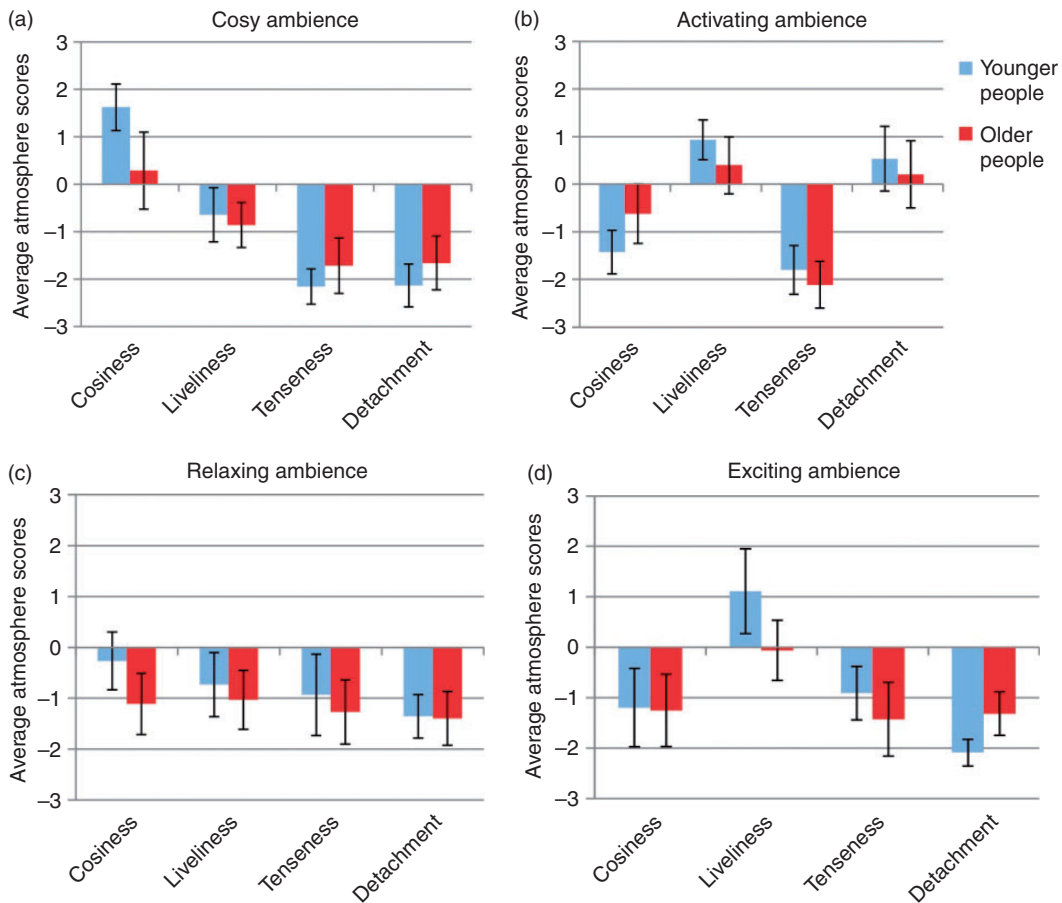


Figure 3 Mean Atmosphere scores on the four dimensions of the Atmosphere questionnaire. The four different graphs represent the four ambiances evaluated by the younger people and older people. The error bars reflect the 95% confidence intervals

separated for each of the four ambiances. Main effects were analysed with the Friedman test; the Wilcoxon signed-rank test was used as *post hoc* analysis with a Bonferroni correction applied, resulting in a significance level set at $p < 0.0083$.

3.6.1. Atmosphere scores for the younger participants

The Friedman test revealed a significant difference in cosiness between the four ambiances ($X^2 = 25.57$, $p < 0.001$). The Wilcoxon signed-rank *post hoc* test revealed that the 'cosy' ambience was scored significantly higher than the three other ambiances: 'relaxing' ($z = 3.02$, $p = 0.003$, $r = 0.55$), 'activating' ($z = 3.35$, $p = 0.001$, $r = 0.61$) and 'exciting' ($z = 3.42$, $p = 0.001$, $r = 0.62$). A significant difference in liveliness was found between the four ambiances ($X^2 = 21.378$, $p < 0.001$). *Post hoc* analysis revealed that the 'activating' ambience was scored higher on liveliness than both the 'relaxing' ($z = 3.01$, $p = 0.003$, $r = 0.55$) and 'cosy' ambience ($z = 2.98$, $p = 0.003$, $r = 0.54$). Furthermore, the 'exciting' ambience was scored higher on liveliness than the 'relaxing' ($z = 3.21$, $p = 0.001$, $r = 0.59$) ambience. The differences in tenseness between the ambiances were found to be significant ($X^2 = 19.919$, $p < 0.001$), although in fact only the 'exciting' ambience and the 'cosy' ambience were scored significantly different ($z = 3.31$, $p = 0.001$, $r = 0.60$). Lastly, a significant difference was found in detachment between the four ambiances ($X^2 = 31.331$, $p < 0.001$). *Post hoc* tests revealed that the 'activating' ambience was scored significantly higher than the three other ambiances; 'cosy' ($z = 3.30$, $p = 0.001$, $r = 0.60$), 'relaxing' ($z = 3.17$, $p = 0.002$, $r = 0.58$) and 'exciting' ($z = 3.31$, $p = 0.001$, $r = 0.60$).

3.6.2. Atmosphere scores for the older participants

For the older people, the 'cosy' ambience received the highest cosiness scores in line with the results for the younger people, but the scores were just above neutral, and not

significantly different from the scores of the other ambiances. A significant effect in liveliness between the four ambiances was found ($X^2 = 11.744$, $p = 0.008$). *Post hoc* tests revealed that the 'activating' ambience was rated significantly higher than both the 'cosy' ($z = 2.77$, $p = 0.006$, $r = 0.42$) and 'relaxing' ambience ($z = 2.94$, $p = 0.003$, $r = 0.45$). All ambiances were scored low on the tenseness dimension with no significant differences between them. The differences in detachment between the ambiances were statistically significant ($X^2 = 14.604$, $p = 0.002$). *Post hoc* tests revealed that the 'activating' ambience was scored significantly higher than the other three ambiances; 'cosy' ($z = 3.55$, $p < 0.001$, $r = 0.55$), 'relaxing' ($z = 3.01$, $p = 0.003$, $r = 0.46$) and 'exciting' ($z = 3.30$, $p = 0.001$, $r = 0.51$).

3.6.3. Comparison of younger with older participants

The scores on the Atmosphere dimensions were found to be significantly different between the younger and older participants with a Mann-Whitney test. The cosiness scores for the 'cosy' ambience were significantly lower for the older participants than for the younger ones ($z = 2.20$, $p = 0.028$, $r = 0.37$). For the 'exciting' ambience a significant difference was found between the two groups of participants on the liveliness dimension ($z = 2.47$, $p = 0.014$, $r = 0.41$) and detachment dimension ($z = 2.38$, $p = 0.017$, $r = 0.40$). All other differences were found to be non-significant.

3.6.4. Affective quality scores for the older participants

Figure 4 shows the average pleasure and arousal scores for the four ambiances assessed by the older participants only. The 'cosy' and 'activating' ambiances received higher pleasure scores compared to the 'relaxing' and 'exciting' ambiances; these differences, however, did not reach significance. The Friedman test revealed a significant difference in arousal between the four ambiances

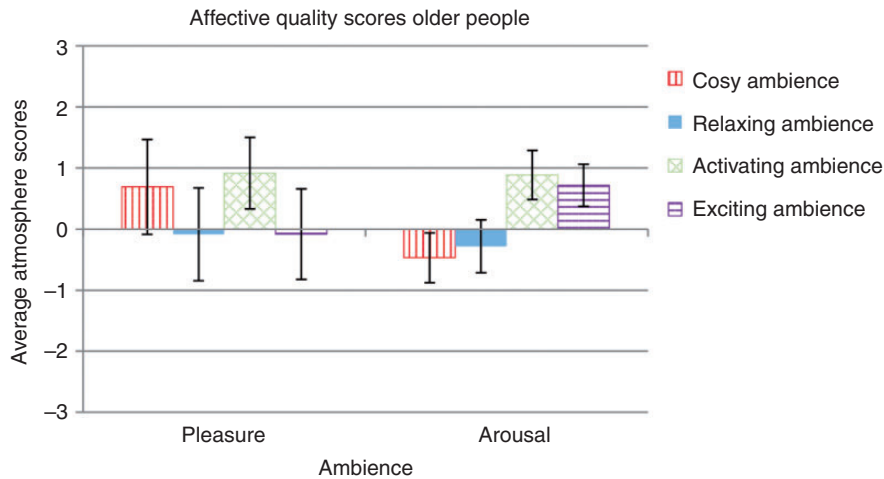


Figure 4 Mean arousal and pleasure scores for the four ambiances, as given by the older people. The error bars reflect the 95% confidence intervals

Table 6 Correlation between the four dimensions of the Atmosphere questionnaire and the pleasure and arousal dimension of the Affective quality attributed to places questionnaire

	Pleasure	Arousal
Cosiness	0.761**	-0.198
Liveliness	0.527**	0.536**
Tenseness	-0.609**	-0.122
Detachment	-0.206	0.113

**means significant at the 0.01 level.

($X^2(3) = 27.218$, $p < 0.001$). *Post hoc* tests showed that the ‘activating’ ambience was scored significantly higher than both the ‘cosy’ ($z = 3.48$, $p < 0.001$, $r = 0.54$) and ‘relaxing’ ($z = 2.90$, $p = 0.004$, $r = 0.45$) ambience; the ‘exciting’ ambience was also scored significantly higher than both the ‘cosy’ ($z = 3.38$, $p = 0.001$, $r = 0.52$) and ‘relaxing’ ($z = 3.66$, $p < 0.001$, $r = 0.56$) ambience.

Table 6 shows the correlations between the four dimensions of the Atmosphere questionnaire and the pleasure and arousal dimension of the Affective quality attributed to places questionnaire. Cosiness is highly correlated with pleasure, liveliness is highly correlated with both pleasure and arousal and tenseness

is highly negatively correlated with pleasure. Detachment is correlated with neither pleasure nor arousal.

3.6.5. Qualitative data

After the experiment, the older people were allowed to comment on the ambiances presented. Most older people reported that the ‘relaxing’ ambience was too dark and they disliked the green and blue colour combination. Several older people commented that the use of different colours in the ‘cosy’ and ‘relaxing’ ambiances gave them a restless feeling. Also the saturated blue light above the table in both ambiances was perceived as cold and uncomfortable. Finally, they commented that they found the ‘exciting’ ambience in general unsuitable for the older population.

3.7. Discussion

With the exception of the ‘relaxing’ ambience, which was perceived as neutral in terms of cosiness and only slightly negative in terms of liveliness, the intended affective connotations of our ambiances were well recognized by the group of younger participants. The ‘cosy’ ambience received high scores on the cosiness

dimension, while the ‘activating’ and ‘exciting’ ambience received high liveliness scores. Conversely, older people did not agree with the intended affective connotation of the ambiances. The ‘cosy’ ambience was rated slightly higher than the other ambiances on cosiness, but this difference was not statistically significant; compared to the group of younger participants, the cosiness scores of the older people were significantly lower. Older people were able to differentiate the low arousing ambiances (‘cosy’ and ‘relaxing’) from the high arousing ambiances (‘activating’ and ‘exciting’) in terms of liveliness and arousal scores. Still, the liveliness scores of both the ‘activating’ and ‘exciting’ ambiances were lower for the older people than for the younger people; for the ‘exciting’ ambience this difference was found to be significant. We can conclude, therefore, that atmosphere perception changes with age, and that designs made with a younger population in mind cannot in general be immediately deemed appropriate for older people.

The qualitative data gave some insights as to why the ambiances were scored differently by the older people. The ‘relaxing’ ambience was perceived as too dark. This may be caused by a decline in the sensitivity to light for the older population.²⁸ Also the use of more than one colour in the ‘relaxing’, ‘cosy’ and especially in the ‘exciting’ ambience was perceived as restless and unsuitable for the older population. This conclusion is in line with the findings of Yildirim *et al.*,³⁰ who showed that older customers appreciate colourful interiors less than younger people. The older people disliked the saturated blue light in the ‘cosy’ and ‘relaxing’ ambience. This result is in agreement with research which states that preference for the colour blue declines with age³¹ and that older people prefer light colours over dark (e.g. highly saturated) colours.³² The use of dynamic lighting in the ambiances for younger participants may also have played a role in

determining the difference in liveliness scores between the two groups. Indeed, it was found in previous research that dynamic lighting may increase liveliness scores.³⁴ The changes in CCT over minutes in the ‘activating’ ambience, on the other hand, are not likely to be responsible for an increase in the liveliness scores, as previous research indicated that slow dynamics (i.e. 16 seconds) do not increase liveliness scores.³⁴ It is instead more likely that the faster dynamics in the lighting of the ‘exciting’ ambience for younger people made the ambience livelier for them.

To summarize, we did not succeed in identifying a low arousal pleasant ambience and a high arousal pleasant ambience that would be clearly recognized by the older people. Nonetheless, we were able to reduce our search space based on the results reported earlier. Among the two candidate low arousal pleasant ambiances (‘cosy’ and ‘relaxing’), the ‘cosy’ ambience was found most suitable to our goals as reflected by the highest cosiness scores, as well as by the high pleasant and low arousal ratings. Similarly, the ‘activating’ ambience was found more suitable than the ‘exciting’ one as a high arousal pleasant ambience, since it received the highest liveliness ratings, as well as higher pleasure and arousal scores.

4. Experiment 2: ‘Cosy’ and ‘activating’ ambiances for older people

We designed a second experiment to improve the ‘cosy’ and ‘activating’ ambiances for older people. To do so, we started from the ambiances used in the previous experiment and modified them according to the comments given by the older participants in Experiment 1. More systematic insights were then collected with an informal photo interview with 12 of the older people that participated in the first experiment. Based on these data, we made changes to the ‘cosy’ and ‘activating’ ambiances and tested whether

these ambiances were more appropriate for the older people.

4.1. Photo interview

Photos were taken of the experimental room under different lighting conditions, including changes in intensity and CCT of the functional lighting and the use of different colours and colour pairs for the accent lighting. The original ‘cosy’ and ‘activating’ ambiances served as starting point. For both ambiances the older people had to comment which changes they felt would make the ambience cosier or livelier, respectively. The results are summarized in Figure 5.

Most older people preferred a higher intensity level in both the ‘cosy’ and ‘activating’ ambience. This finding is supported by research stating that older people need more

indoor illumination compared to younger people as a result of a loss in sensitivity in the visual system with age.²⁸ Consequently, we increased the illuminance by 50% in the ‘cosy’ ambience and by 35% in the ‘activating’ ambience, as can be seen in Table 7. In general, no changes in CCT were preferred. For both ambiances most older people

Table 7 Light characteristics of the four ambiances used in experiment 2; vertical illuminance and CCT were measured at the eye position

Ambience	Illuminance (lx)	CCT (K)	Hue pairs
Cosy	80	2700	Orange, blue
Cosy older people	120	2700	Only orange
Activating	240	4000	Cyan, blue
Activating older people	325	4000	Only cyan
Neutral	150	3400	Only white

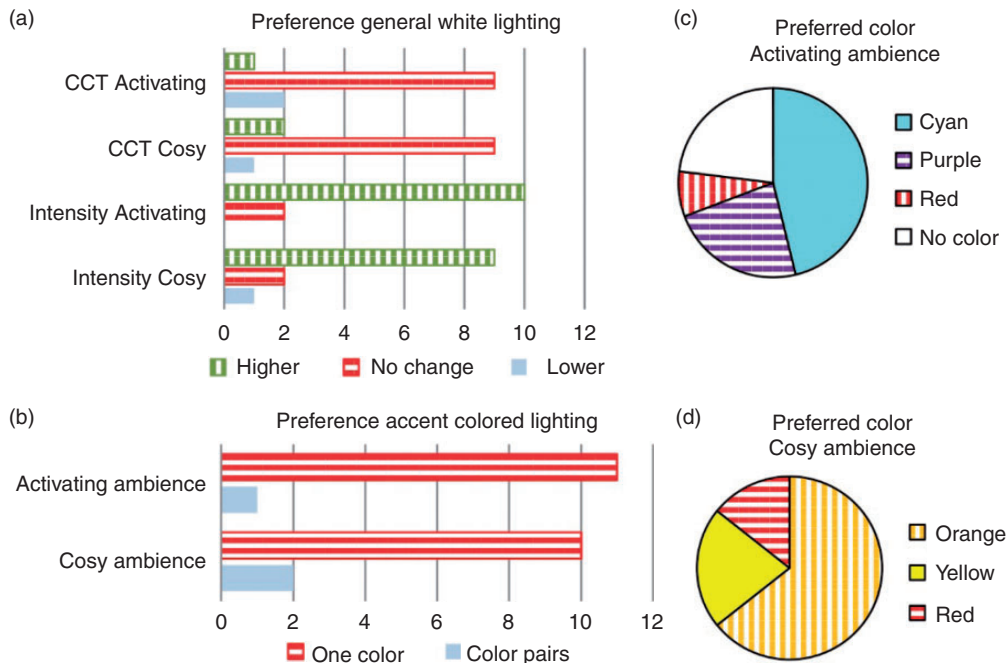


Figure 5 Preferred changes in the ‘cosy’ and ‘activating’ ambience as indicated by the older people: (a) represents the number of participants that wanted to increase, decrease or not change the intensity or CCT of the general white lighting; (b) represents the number of participants that wanted to have just one colour or a pair of colours in the accent lighting; finally (c) and (d) give pie charts of the preferred colours used in the ‘activating’ and ‘cosy’ ambiances, respectively

preferred to have only one colour for the accent lighting in the ambience; this colour was preferably in the yellow to red spectrum for the ‘cosy’ ambience, whereas the preference for a specific colour was less pronounced for the ‘activating’ ambience. As a consequence, we used only orange accent lighting in the new ‘cosy’ ambience – hereafter referred to as ‘cosy older people’ – and only cyan accent lighting in the new ‘activating’ ambience – hereafter referred to as ‘activating older people’ – as is also indicated in Table 7.

4.2. Experimental design

4.2.1. Participants

Fifteen older people participated in the second experiment; their ages ranged from 65 to 88 years ($M = 73.1$ years, $SD = 7.5$). All

participants were native Dutch speakers and did not suffer from colour blindness.

4.2.2. Experimental room and installed luminaires

The experiment took place in the same experimental room with the same luminaires installed as in the first experiment. The Gemini table lamp now illuminated the table with white light in the new ‘activating older people’ ambience.

4.2.3. Stimuli

The original ‘cosy’ and ‘activating’ ambiances created by lighting designers were evaluated together with the ambiances adjusted specifically for the older people: ‘cosy older people’ and ‘activating older people’. Representative pictures of the four ambiances used in the experiment are shown in Figure 6, while the corresponding light

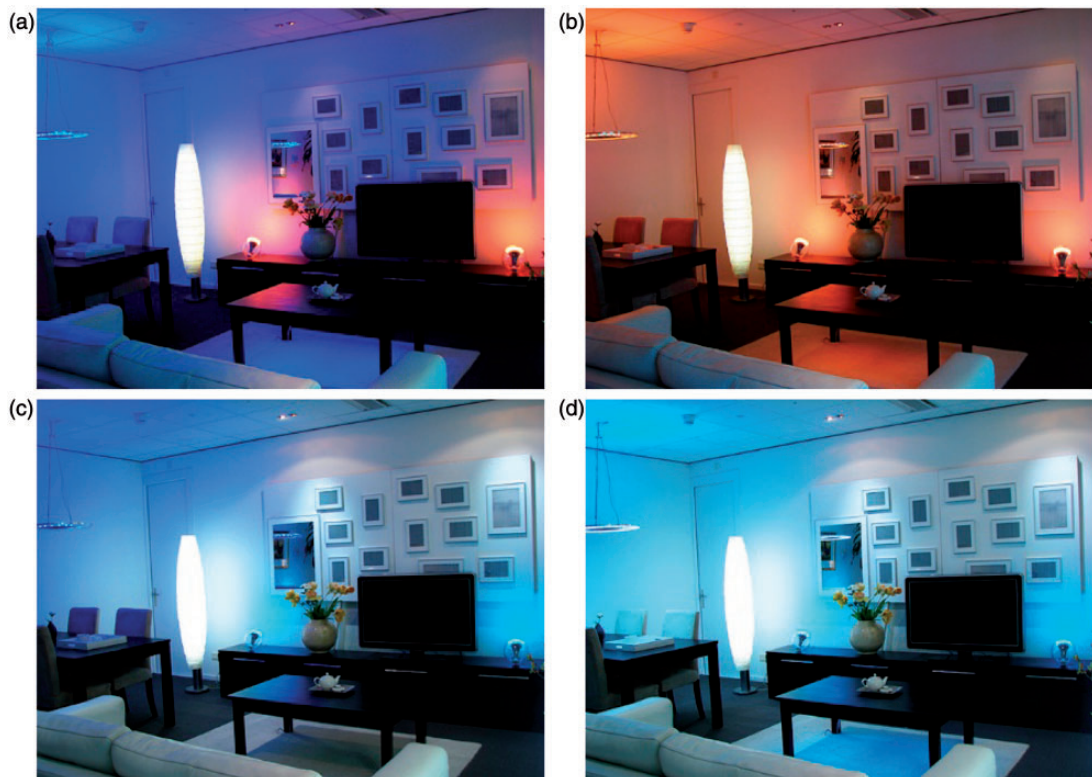


Figure 6 An impression of the ambiances used in experiment 2, reflecting (a) ‘cosy’, (b) ‘cosy older people’, (c) ‘activating’ and (d) ‘activating older people’ ambience. (Available in colour in online version)

characteristics, measured as vertical illuminances and CCT, are summarized in Table 7. While switching between the ambiences, we again showed the neutral ambience for 30 seconds. The neutral ambience only consisted of functional white lighting with a neutral CCT (3400 K) and intermediate illumination (150 lx).

4.2.4. Measurement method

Since in the first experiment we found the pleasure and arousal dimensions of the Affective quality questionnaire to be correlated as expected with the most important Atmosphere dimensions, i.e. cosiness, liveliness and tenseness, we decided to evaluate the ambiences only with the Atmosphere questionnaire in this second experiment. In this respect, we again used the same short version of the questionnaire as given in Table 4.

4.3. Results

The inter-rater reliabilities were determined by computing Cronbach's alpha over the items for the four Atmosphere dimensions. Acceptable to good reliabilities were obtained with $\alpha=0.83$ for cosiness, $\alpha=0.80$ for

liveliness, $\alpha=0.81$ for tenseness and $\alpha=0.76$ for detachment. Again, the Cronbach's alpha is slightly lower for the items covering the detachment dimension than for the other dimensions.

Figure 7 presents the scores averaged over the participants for the four Atmosphere dimensions for each of the four ambiences. For the analysis, we again used the Friedman test to evaluate statistical significance for the main effects. The Wilcoxon signed-rank test was used for the *post hoc* analyses, again using a Bonferroni correction for the multiple comparisons between levels in the independent variable, resulting in a significance level set at $p<0.0083$.

The Friedman test revealed a significant difference in cosiness between the four ambiences ($X^2(3)=22.627$, $p<0.001$). *Post hoc* tests showed that the 'cosy older people' ambience was scored significantly higher than the other three ambiences: 'cosy' ($z=2.73$, $p=0.006$, $r=0.50$), 'activating' ($z=3.35$, $p<0.001$, $r=0.61$) and 'activating older people' ($z=3.41$, $p<0.001$, $r=0.62$). Also with respect to the liveliness dimension,

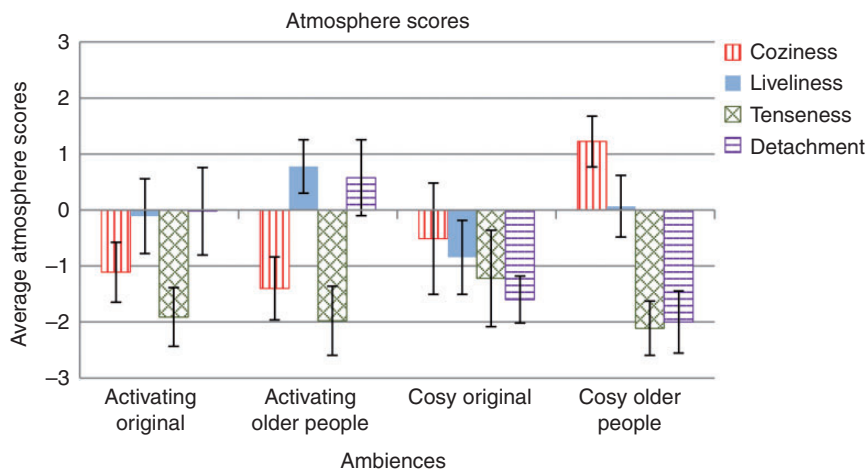


Figure 7 Mean scores for the four ambiences evaluated in experiment 2. The different bars represent the four different Atmosphere dimensions. The error bars represent the 95% confidence intervals

a significant effect was found ($X^2(3) = 13.809$, $p = 0.003$). *Post hoc* tests revealed that the 'activating older people' ambiance was scored significantly higher than both the 'activating' ($z = 2.64$, $p = 0.008$, $r = 0.48$) and 'cosy' ($z = 2.92$, $p = 0.003$, $r = 0.53$) ambience. All the four ambiances were scored negatively on the tenseness dimension; mutual differences were not statistically significant. The Friedman test also showed a significant difference in detachment between the four ambiances ($X^2(3) = 27.725$, $p < 0.001$). *Post hoc* tests showed that the 'activating older people' ambiance was scored significantly higher than both the 'cosy' ($z = 3.11$, $p = 0.002$, $r = 0.57$) and 'cosy older people' ($z = 3.06$, $p < 0.002$, $r = 0.56$) ambience. Also the 'activating' ambiance was scored significantly higher than both the 'cosy' ($z = 2.66$, $p < 0.008$) and 'cosy older people' ($z = 3.19$, $p = 0.001$, $r = .58$) ambiances.

4.4. Discussion

The intended affective connotation of the adjusted ambiances was better recognized by the older participants than the affective connotation of the original ambiances. With the adjustments applied to the ambiances, the 'cosy older people' ambiance received the highest cosiness scores, and the 'activating older people' ambiance received the highest liveliness scores. The adjustments made in the 'cosy older people' ambiance, i.e. limiting the accent lighting to one colour (i.e. orange) and increasing the general illumination of the white light, resulted in a significantly cosier perceived atmosphere for the older people. The adjustments in the 'activating older people' ambiance, which consisted of limiting the accent lighting again to one colour (i.e. cyan), directing the white light towards the table and increasing the general illumination of the white light, resulted in a significantly livelier perceived atmosphere for the older people.

5. Overall discussion and conclusions

This paper describes the creation and evaluation of a pleasant low arousal ambiance (i.e. 'cosy') and a pleasant high arousal ambiance (i.e. 'activating') for older people. The ambiances created for younger people with the input of lighting designers serving as starting point needed adaptation to become recognizable as intended by the older people. Illuminances needed to be increased, saturated blue light was excluded and colour pairs were avoided. These changes were largely in line with what could be expected from the literature based on ageing in the human visual system^{28,29} and on differences in colour preference with age.³²

Despite their alignment with results existing in the literature, it should be noted that the changes we made to the ambiances were actually determined based on a rather informal photo interview with a selected group of older people. Although this approach led to valuable results (the new ambiances were indeed improved in the recognizability of their affective connotation), the approach does not guarantee them to be optimal in terms of being cosy and activating. On the other hand, the knowledge available in literature is also still not comprehensive enough to design optimal ambiances in a well-controlled way; this justifies the somewhat informal approach. More research in this sense may allow creating even more pronounced 'cosy' and 'activating' ambiances for older people.

An additional limitation of the current study is that we considered the average of the older people as the ambiance judge and didn't look into individual differences. It is known that the human visual system still largely degrades with age above 60 years,³⁵ and so our group of participants definitely was not uniform in terms of intensity sensitivity and colour perception. On top of these differences in the human visual system, individual preferences may have an impact on what the optimal 'cosy' and 'activating' ambiances should look like. Thus, only considering an

averaged older person may result in sub-optimal ambiances for some participants. The latter become even more important when measuring to what extent the perceived atmosphere changes an older person's mood in the intended direction. Having personalized ambiances may then help to make the intended change in mood more pronounced.

Despite these limitations, we may conclude that it is possible to use lighting to create a pleasant low arousal ambience (i.e. 'cosy') and a pleasant high arousal ambience (i.e. 'activating') for older people. For the pleasant low arousal ambience, older people prefer functional white lighting with a low colour temperature (reddish white light) in combination with warm coloured accent lighting (orange). For the pleasant high arousal ambience, older people prefer white lighting with a high colour temperature (bluish white light) with cyan coloured accent lighting. The use of colour pairs should be avoided; older people prefer to use only one colour in their accent lighting.

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