The Influence of Lighting Color and Dynamics on Atmosphere Perception and Relaxation

S. H. Wan,[1] J. Ham,[1] D. Lakens,[1] J. Weda[2], & R. Cuppen[2]

[1] *Eindhoven University of Technology, Eindhoven, the Netherlands*
[2] *Philips Research, Eindhoven, the Netherlands*

Introduction

Although a small amount of stress can motivate and help us to be more productive, prolonged or large amounts of stress can have a negative effect on personal health (Wilke, Gmelch, & Lovrich, 1985). Earlier research suggested that certain characteristics of environments (e.g., lighting, sound) can reduce stress experiences (Borland, 2010; Forgays & Belinson, 1986). These studies mainly investigated effects of static lighting, and of lighting that changed very quickly (faster than 1 Hz; creating negative effects) or lighting that changed very slowly (too slow to consciously perceive).

In the current research, we argue that also dynamic lighting employing slow but perceivable changes can lead to changes in atmosphere perception and to relaxation. Support for this might be found on research on relaxing effects of music that suggested that soft, predictable, monotonous and slow tempo music can lead to lower arousal levels (Caldwell & Hibbert, 2002). In general, an environment can support stress restoration and improve the effectiveness in facilitating stress coping (Ulrich, 1991). Ulrich (1991) suggested that the physical environment can provide positive distractions (e.g., music in a hospital) that elicit positive feelings and holds attention and interest without taxing or stressing the individual, and thereby may block or reduce worrisome thoughts. Similarly, we argue that slow but perceivably changing dynamic lighting may serve as a positive distractor and thereby reduce stress levels.

Therefore, we investigated the influence of pulsating lighting vs. static lighting on atmosphere perception and stress-recovery.

Furthermore, lighting can influence atmosphere perception (Seuntiens & Vogels, 2009; Vogels, 2008). Specifically, certain lighting temperatures (e.g., ca. 2700 K) might create a cozy and relaxing atmosphere (Seuntiens & Vogels, 2009), and might (indirectly) influence affective states (Vogels, 2008). A pretest (assessing various lighting colors and various paces of saturation pulsation) we performed suggested that orange colored lighting was perceived as a relaxing atmosphere. To test whether especially orange colored, pulsating lighting might lead to both positive atmosphere perception and relaxation, we investigated the influence of (pulsating versus static) lighting that was either orange or white (control condition) on atmosphere perception and stress-recovery. We expected that pulsating lighting would lead to lower stress levels than static lighting. Also, we expected that orange lighting color would lead to lower stress levels than the white lighting color, and that especially orange pulsating lighting will lead to lower stress levels, relaxation and positive atmosphere perception.

Method

Participants and Design

Eighty-two Dutch participants recruited via a mailing list (48 male and 34 female, mean age, $M = 28$, $SD = 11$) participated in one of the conditions of a 2 (color: orange vs. white) x 2 (lighting setting: pulsating vs. static) between participants design. Thereby, each participant participated in only one of the four experimental conditions (20 participants in the white static and orange static conditions and 21 participants in the white dynamic and orange dynamic conditions). Participation lasted approximately 40 minutes, and participants were paid € 7.50.

Apparatus

The NeXus-10 recording device and accompanying sensors (Mind Media BV, Roermond, The Netherlands) was used to measure physiological stress-related responses (interbeat interval, and Galvanic skin response).

To display either pulsating or static, orange or white lighting, we used wall-washers (ColorGraze Powercore linear LED, Philips Lighting). We used two rows of wall-washers attached on the ceiling, projecting light on two sides in the lab room, on the left hand and right hand side of the participant's desk. The fluorescent tube lighting in the ceiling was on during the pretest and did not change.

Lighting stimulus

A pretest was conducted to investigate the appropriate settings for the lighting stimulus. The results of this pretest suggested that an orange colored lighting setting with medium paced (.125 Hz) pulsations was the most preferred for relaxation. This lighting setting varied in saturation, whereas the white colored lighting condition varied in intensity (Fig. 1).

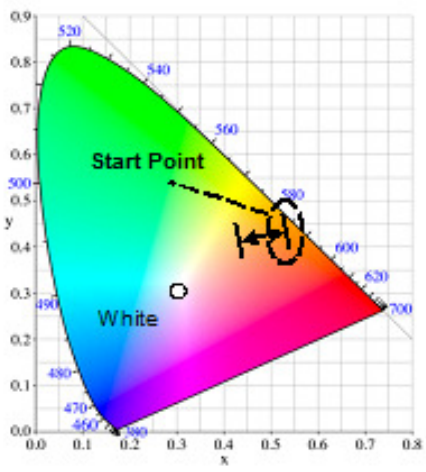

Fig. 1: The lighting stimuli shown in the CIE color space model

Measurements

Both psychological and physiological measurements of stress were conducted during the experiment. Twenty questions assessing state anxiety were derived from the state-trait anxiety inventory (STAI) of Spielberger, Gorsuch and Lushene (1970) and formed a reliable measure for state anxiety (α = .96). Atmosphere perception in the lighting lab was measured using a twelve items version of the atmosphere perception scale (Vogels, Sekulovski, Clout, & Moors, 2009). A factor analysis indicated four dimensions in this scale. Therefore, we combined the corresponding three questions for each dimension to form a reliable measure for coziness (α = .77), liveliness (α = .76), tenseness (α = .84) and detachment (α = .79).

Heart rate (HR) was measured using the NeXus-10 Blood Volume Pulse Sensor at the middle finger of the left hand. Galvanic skin response (GSR) was measured using GSR electrodes at the index and ring finger of the left hand.

Procedure

Each participant was seated in front of a desk on which a computer screen was placed (for displaying questions and instructions). The distance between the screen and the participant's head was approximately 70 cm.

The experiment started with general instructions and the attachment of physiological sensors. After that physiological responses were recorded continuously. Next, a video clip about underwater life (Hannan, 1992) was shown for 480 seconds. Watching this video clip is used as a neutral task. Next, participants were asked to fill out the state anxiety inventory. Finally, participants filled out the atmosphere perception questionnaire followed by demographic questions (e.g., gender, age). After the experiment was completed the physiological sensors were removed from the participant, and participants were thanked for their participation. During the whole experiment (from before the participant entered the room, until after he or she left), the pulsating or static, orange or white lighting was turned on. Each participant was subjected to only one lighting setting and were asked whether they noticed the lighting pulsations in the end. The total duration of participation including the instructions and the attachment and detachment from the physiological equipment was approximately 40 minutes.

Results

To assess the influence of lighting condition on reported (psychological) relaxation, we submitted the state anxiety score to a 2 (color: orange vs. white) x 2 (lighting dynamics: pulsating vs. static) ANOVA, in which both factors were manipulated between participants. This analysis provided no evidence in support of our expectation that orange lighting would lead to lower state anxiety than white lighting, $F < 1$, nor did this analysis provide evidence that pulsating lighting lead to lower state anxiety than static lighting, $F < 1$. However, this analysis did support our expectation that pulsating (versus static) lighting had a different influence on state anxiety for different colored light, indicated by an interaction of lighting color x lighting dynamics, $F(1, 78) = 13.10$, $p < .05$, $\eta_p^2 = .14$. That is, participants for whom the lighting was orange and pulsating ($M = 13.81$, $SD = 10.70$) and those for whom the lighting was white and static ($M = 14.37$, $SD = 9.48$) scored lower on the state anxiety inventory, than participants for whom the lighting was orange and static ($M = 22.40$, $SD = 11.83$) and those for whom the lighting was white and pulsating ($M = 23.72$, $SD = 12.58$).

To assess the influence of lighting condition on physiological relaxation, we selected a 60 seconds end period of the video clip to compute the means of the Interbeat Interval (IBI) and standardize Galvanic Skin Response (GSR) scores. These mean scores were submitted to the same ANOVA. This analysis provided no evidence for our expectations that lighting color or dynamics would influence physiological relaxation, all F's < 1. Results provided no evidence for a correlation between physiological measures and the STAI.

Furthermore, to assess the influence of lighting condition on atmosphere perception, we submitted a participant's scores on the four atmosphere perception dimensions to the same ANOVA. In line with our first expectation, this analysis suggested that participants judged the orange lighting condition to be more cozy ($M = 14.63$, $SD = 3.39$) than the white lighting condition ($M = 11.27$, $SD = 4.43$), $F(1, 73) = 13.96$, $p < .01$, and the orange lighting condition to be less detached ($M = 7.68$, $SD = 3.51$) than the white lighting condition ($M = 12.89$, $SD = 4.16$), $F(1, 73) = 34.91$, $p < .01$. Also, in line with our second expectation, this analysis suggested that participants judged the pulsating lighting condition to be more lively ($M = 13.97$, $SD = 4.06$) than the static lighting condition ($M = 11.98$, $SD = 4.08$), $F(1, 73) = 4.25$, $p < .05$. This analysis provided no evidence for our expectation for an interaction between lighting dynamics and lighting color on atmosphere perception, all F's < 1. All participants in the pulsating lighting condition mentioned that they noticed the lighting pulsations.

Discussion

To investigate whether a calming environment can be created that diminishes stress levels, the current research investigated the influence of pulsating lighting on atmosphere perception, and psychological and physiological stress. Participants performed a neutral task (watching the video clip about underwater life) in a room that contained lighting that displayed on a wall slowly pulsating (.125 Hz) or static, orange or white lighting.

Results provided no evidence that, overall, orange lighting leads to lower stress levels (neither psychological nor physiological), nor that orange lighting in general leads to lower stress levels than white lighting. However, results did suggest that orange and pulsating, and also static white lighting leads to lower psychological stress levels than static orange or pulsating white lighting. Furthermore, in line with earlier findings, results suggested that orange lighting conditions created a more relaxed (more cozy, less detached) atmosphere than white lighting conditions.

Thereby, the current results suggested that adding slow pulsations to orange colored lighting might support stress-reduction while creating a relaxed atmosphere. Future research could investigate using pulsating orange lighting to ameliorate conditions in

stressful situations, as for example hospital waiting rooms.

As for the concept of positive distraction (Ulrich, 1991), our results suggested that simply adding pulsations to lighting may not be sufficient as a positive distractor. One should consider whether the lighting elicits positive feelings and can subtlety distract people from their stressing thoughts, because not all lighting colors with pulsations may elicit positive feelings (cf., our white pulsating lighting). Future research is needed to investigate whether orange colored lighting with pulsations could serve as a positive distractor.

The current research did not provide evidence of effects of pulsating lighting on physiological measures of stress. This might be due to noise and other measurement issues, but could also suggest that effects of pulsating, orange-colored lighting are primarily psychological. Future research can continue this investigation, for example by exploring other physiological measurements of stress. In addition, the current research tested a limited set of lighting parameters (color, pulsation) for their effects on relaxation. Future studies should focus on investigating the boundaries of settings in terms of hue, saturation and tempo, when pulsating lighting is perceived as a positive distraction or as annoying.

In conclusion, the current research explored a new kind to stress reduction technology--the possibilities of pulsating (orange) lighting to support stress-recovery. This study revealed preliminary results that suggest that specific forms of pulsating lighting (e.g., orange) might support stress-recovery. Further research is needed to augment these findings, which can possibly lead to designing new forms of healing environments, like waiting rooms in hospitals that help patients relax.

References

Borland, I. (2010). The effectiveness of Snoezelen sensory-based behavioural therapy on individuals with Dementia. *Mental Health CATs, 16*.

Caldwell, C., & Hibbert, S. A. (2002). The influence of music tempo and musical preference on restaurant patrons' behavior. *Psychology and Marketing, 19*(11), 895-917

Forgays, D. G., & Belinson, M. J. (1986). Is flotation isolation a relaxing environment? *Journal of Environmental Psychology, 6*(1), 19-34.

Hannan, D. (Writer). (1992). Coral Sea Dreaming, *an evolving balance*. Australia.

Seuntiens, P. J. H., & Vogels, I. M. L. C. (2009). Atmosphere creation: the relation between atmosphere and light characteristics. Unpublished Technical Note. Philips

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). State-trait anxiety inventory. *Consulting Psychologists Press*.

Ulrich, R. S. (1991). Effects of interior design on wellness: theory and recent scientific research. *Journal Health Care Interior Design, 3*, 97–109.

Vogels, I. (2008). Atmosphere metrics. In J. H. D. M. Westerink, M. Ouwerkerk, T. J. M. Overbeek, W. F. Pasveer & B. Ruyter (Eds.), *Probing Experience* (Vol. 8, pp. 25-41): Springer Netherlands.

Vogels, I., Sekulovski, D., Clout, R., & Moors, R. (2009). A quantitative study on the impact of light on the atmosphere of an environment. Philips Research Europe.

Wilke, P. K., Gmelch, W. H., & Lovrich, N. P. (1985). Stress and productivity: Evidence of the inverted U function. *Public Productivity Review, 9*(4), 342-356.