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Foreword

Light existed well before humans did. We evolved as organisms exposed to the daily cycle of light and dark, completely at the mercy of weather and seasonal influences. Then – over the course of millenniums – we gradually learned to control it. We now live in an era in which light appears to be ubiquitous and is often taken for granted. Still, we are only beginning to learn just how profound and multifaceted light's impact is on human functioning. Experiencing Light 2012 was organized in an attempt to facilitate this process.

The first edition of this conference in 2009 can only be called a success. Its goal was to bring together a multidisciplinary group of researchers and designers working in this domain so they could meet, share experiences, present research, and exchange ideas about light and its relationship to human wellbeing. And it worked: we had well over a hundred participants, from twenty-one different countries. Participants were affiliated to academia and research institutes mainly, but we also had a substantial number of people from industry (lighting, design, consultancy). We therefore concluded that Experiencing Light 2009 provided a timely and necessary international forum to discuss the impact and relevance of recent technological, societal and scientific developments in the lighting domain on user experience.

Now, in 2012, the conference theme still appears as timely and necessary as it was three years ago. Much has happened. In our own university we have seen the establishment and development of the Intelligent Lighting Institute (ILI), in which engineers, designers, and social scientists collaborate to investigate and develop innovations in lighting. Similar cross-disciplinary collaborations are emerging across the globe. We are both happy and proud to see such different groups also represented here today. We welcome you all, 'veterans' and 'newbies' alike.

The program of Experiencing Light 2012 consists of exciting keynote addresses by Andrew Elliot, Debra Skene, and Har Hollands. It furthermore includes twenty nine orals and nineteen interactive posters, on new research and findings, new conceptualizations and designs, and new reflections on light and its psychological impact. The extended abstracts you find in these proceedings were selected from the large collection of submitted papers through a carefully conducted review process, using blind peer-review. We are greatly indebted to the members of the Scientific Committee for their excellent work in reviewing the submitted papers that accompany the interactive posters are also included in these proceedings.

This year we also organized a doctoral consortium, preceding the conference. This intensive and interactive day was geared towards in-depth mentoring of PhD students working in this exciting but complex domain of light and the human experience. We owe lots of thanks to the mentors – all participants of the conference – who were willing to sacrifice their Sunday for this event and share their insights with tomorrow's experts.

We gratefully acknowledge the sponsors of Experiencing Light 2012: ILI, HTI, Waldmann, and Davita. We thank the Glow festival for providing the perfect backdrop against which to host our conference. Moreover, we would like to thank those who supported the organization of Experiencing Light 2012 and who worked hard to make it a successful event: our keynotes, our secretarial and logistics support, and our student volunteers. Thank you all.

We wish all of you a fruitful and inspiring conference!

Organizers of Experiencing Light 2012:

Yvonne de Kort, Mariëlle Aarts, Femke Beute, Wijnand IJsselsteijn, Antal Haans, Daniel Lakens, Leon van Rijswijk, and Karin Smolders

Impact of Lighting Design on Brand Image

M. Leudesdorff¹, & T. Schielke²

¹ KTH Royal Institute of Technology, Stockholm, Sweden ² Darmstadt University of Technology, Darmstadt, Germany

Introduction

Building history reveals that companies make use of architectural design and symbols to communicate their brand identity (Messedat, 2005). Consistent design concepts for retail outlets of a brand help a company to form a uniform image to the consumer for a clear brand identity. In contrast to design like colour, material parameters and furniture, which have been established more widely in the 1960ies within corporate visual guidelines (Meggs, 1983), the aspect of lighting design is relatively new. In marketing a brand is regarded as "a name, term, sign, symbol or design, or a combination of them, intended to identify the goods or services of one seller or group of sellers and to differentiate them from those of competitors" following the definition of the American Marketing Association (Kotler 2000). Therefore the aim of a brand communication strategy from a company as a sender is the brand image in the mind of the customer as a receiver. The so called visual identity of a brand (Kirby and Kent, 2010), as well as the actual personality of a brand (Aaker, 1997) are long known characters when it comes to conveying a certain shopping experience and to increase sales.

Theoretical Background

From the semiotics perspective, architecture can be seen as a symbol (Nöth, 1985). Building history reveals that companies make use of architectural design and symbols to communicate their brand identity (Messedat, 2005). Consistent design concepts for retail outlets of a brand help a company to form a uniform image to the consumer for a clear brand identity. For brand classification a two-dimensional milieu studies exists, which focuses on social status and value orientation (Becker and Nowak,

1982). Additionally to the broad application of the Sinus milieu, Raffelt has developed a psycho-lexical inventory to cover the design dimensions, which determine the architectural expression as well as the relevant brand-related response dimensions (Raffelt 2011). She examined the branding literature and linked prototypical design types in architecture to brand impressions. The brand personality was intensely discussed through Aaker in which she defines it as the "set of human characteristics associated with the brand" (Aaker, 1997). Due to cultural differences in brand personality, Raffelt deduced from literature and by tests a scale for empirical studies about architectural design in Germany. A four-factor solution was judged most adequate to capture the data and explained more than 80% of the brand personality variances: Temperament, competence. and naturalness. attractiveness, Flynn observed that bright spaces appear significantly clearer and more spacious in comparison to darker situations (Flynn, 1977). Customers examine more products under bright versus soft lighting (Areni and Kim, 1994), which could be linked to attractiveness. A bright environment could also be regarded as an association to daylight and respectively to naturalness. Hence, the hypothesis is generalized for all parameters:

H1: Brightness leads to higher values for (a) price, (b) style, (c) temperament, (d) competence, (e) attractiveness, and (f) naturalness.

From the perspective of lighting technology it would be interesting, if a change in the lighting concept from general lighting to accent lighting or another type of lighting would achieve a significant change in the brand image. Due to the fact that general lighting with downlights is often linked to low budget environments the hypothesis states:

H2: Illumination with downlights leads to lower values for (a) price, (b) style, (c) temperament, (d) competence, (e) attractiveness, and (f) naturalness when compared to wallwashing and accent lighting.

The question of efficiency plays a vast role during the design process in order to manage the investment and operating costs (Boyce, 2003). Given that brightness, in this case meaning high energy consumption, might not be an indicator for the actual prize perception in a store, the question arises that this can be also true regarding the total costs of a lighting concept. As a consequence, the hypothesis is assumed as follows:

H3: The (a) investment and (b) operating costs of a store's lighting do not correlate with the price perception.

Methodology

To examine the hypothesis that changing the lighting concept is sufficient to change the brand image of a space, an empirical investigation was conducted. To obtain an evaluation of different lighting and room situations, the test participants were asked to give their judgment on light and brand issues. A seven-level Likert scale was used to stimulus and subjective quantify this reactions with "strongly disagree" and "strongly agree" at the end of the axis and a "neutral" in the middle of the scale. In total 20 items were measured. The light was evaluated via the following eight factors: Bright, Dark, Non-uniform light, Uniform light, Cold, Warm, Coloured, Colourless.

For brand classification a two-dimensional milieu study exists, which focuses on social status and value orientation (Becker and Nowak, 1982). For price index as an indicator for social status "High class" and "Low budget" are used as items. The style as a marker for value orientation consists of the items "Modern" and "Traditional".

Raffelt's value sets were reduced to the two highest values of each brand personality to enable the planned light experiment with eight scenes in an adequate time period without fatigue. Each of the four brand dimensions by Raffelt was evaluated with two items: Smart and progressive for temperament, reputable and competent for competence, glamorous and elegant for attractiveness, close to nature and natural for naturalness. Based on four store stereotypes, four lighting concepts were designed, each related to one store stereotype. To enhance the visual perception of these spaces regarding the further process, a 3D lighting calculation program was applied to create visualizations for each space (see Figure 1). For reasons of comparison, all store stereotypes were combined with each light scene, which means 16 different scenes were generated. The simulations were embedded in an internet-based survey to allow participants from different countries an easy access to the experiment.

Experiment

Considering the evolution and resulting diversity in the field interior spaces dealing with a brand image, for reasons of clarity and expense, the study was narrowed towards fashion stores. Due to its reduction to the essence of only one identity and brand (Hassanzadeh, 2009), the paper was further confined to single-brand stores (Dirks, 2009). Based on a thorough review and analysis of the literature, four abstract store concept stereotypes, covering the main reach of store stereotypes, were created: Low Budget, Colour, Black Box, and Minimalism.

The lighting for the low budget stereotype was based on a uniform lighting design with recessed downlights to enhance a functional and simple appearance. In contrast, accent lighting and coloured projection on track mounted luminaires created effect lighting for the colour shop concept. The black box design was based on grazing and accent light by track mounted luminaires to create an intense contrast. Additionally. the minimalistic concept used recessed downlights and wallwashers for an even illumination of the surfaces.

The visualizations (800 x 305 px) were based on DIALux, using digital luminaires with included geometry and IES data format. The sample consisted of altogether 119 people, divided in 51 for group 1 (store types low budget and colour) and 68 for group 2 (store types black box and minimalism).

Results

For hypothesis 1 a simple linear regression analyses was calculated for each group. For group 1 brightness exists as a predictor for price and style. A high brightness level leads to a higher price perceptions; B (SF) = 0,568 (0,169), Exp(B) = 0,433, p = .002, adjusted $R^2 = 0,171$. A positive relationship can be observed for style as well; (SF) = 0,440 (0,171), Exp(B) = 0,344, p = .013, adjusted $R^2 = 0,101$. Hence, the hypothesis H1 can be confirmed for (a) price and (b) style for the group 1.

Group 2 has brightness as a predictor for naturalness. A higher brightness causes a higher index for naturalness; (SF) = 0,305 (0,143), Exp(B) = 0,256, p = .037, adjusted $R^2 = 0,051$. As a result the hypothesis can only be confirmed for (f) naturalness.

For proving the hypothesis 2 a Friedman test was carried out with Bonferroni adjustment, because a normal distribution was mainly not given. Significant differences occur for the space "low budget" for style, competence and naturalness. The "color" space has significant differences for price, style, temperament and competence. For "minimal" interior a significant difference for price. style. competence. exists attractiveness and naturalness. The "black box" type shows significant differences for price. temperament. competence. attractiveness and naturalness. As a result the hypothesis is proved for "black box" in all aspects from (a) to (e) and a counter evidence for (f) style. For "minimalism" the hypothesis could be confirmed for (b) and the contrary for (d) and (e) is proved. For "colour" the hypothesis for (a) to (d) is verified. For "low budget" the hypothesis is confirmed for (b) and a counter evidence given for (d) and (f). This analysis shows that comparing general lighting with downlights significantly affects multiple brand indexes when compared to wallwashing and accent lighting. general the downlight In

illumination leads to lower values for (b) style and partly for (a) price and (c) temperament. Higher values occur with downlights in parts for (f) naturalness.

For hypothesis 3 the calculations for the costs are based on DIN 5035 part 1, 3500 h/year as the estimated operating time for luminaires in retail lighting, price information produced by lighting companies in 2011. Due to present price levels in Germany, the price per kilowatt hour is estimated with 0.17 EUR/kWh throughout all calculations. To get to the total operating costs, the investment costs, which include interest and amortization for each luminaire and other components of 10% per year, were included as well as estimated costs for maintenance, light sources and electricity. After calculating the costs per year of all scenes separately, a correlation analysis is conducted to find out more about how and to what extent the two factors of evaluated prize perception and actual operating costs per year are connected to each other. The outcome of the correlation analysis for evaluated prize perception and actual operating costs per year with 0.205 indicates no significant correlation between both terms and thereby the hypothesis can be regarded as true. Further, no outstanding connection between operating costs and the perception of attractiveness can be found with a correlation value of costs = 0.15. Even though the light scene being the most attracting one for each store stereotype, in three of four cases is the most expensive one regarding operating costs.

Discussion

Since the amount of research in the field of light and store design today is still scarce, this paper contributes to the limited literature testing the impact of lighting concepts on the brand image. The question of how these findings can be translated into real store lighting is dependent on the effect that a brand wants to achieve and whether the case in hand concerns a new lighting concept or an existing installation. This means that it might not always be necessary to completely refurbish a store's lighting scheme. It may be sufficient to only replace specific light settings to make a stronger statement.

Finally, this paper can be regarded as a basis for the general impact of an aligned lighting concept towards a store's image. As a result, the findings on the perception of light in retail spaces can be used to build up more detailed or even experimental studies for each individual topic.

The results reveal that the lighting effect on the brand image is dependent on the interior design concept even though the indexes for style and temperament are consistent for all interiors. Some interior concepts show different relations for the three alternative lighting types when compared to downlight illumination. Mainly the downlight illumination is associated with lower brand index values in comparison to the three alternative lighting scenes with the exception of the naturalness index where higher values mostly occur for downlights.

The conclusion that the perceived prize perception of a store is independent of the actual investing and running costs reveals a new approach to lighting concepts in retail environments. Regarding especially the overall operating costs, a better store image due to aligned lighting does not necessarily go along with higher energy costs.

Implications

The limitations of this thesis lay in the internet-based survev as an abstract illustration of a real architectural space as well as in the number of tested stereotypes for store concepts. The all in all 16 different variations of store concepts combined with lighting scenes do not cover all possible types of store design, but try to cover the main common ones. Further, this study is limited to fashion stores as an example sector of a vast amount of different retail spaces and environments. This aspect requires consideration for the generalization of the economical findings as well.

Outlook

An enlarged investigation with a bigger sample group could help to achieve more concrete findings, considering for example potential cultural differences as well as local retail trends. Moreover, future research could examine, how or to what extent the given findings are applicable to mock-ups in a real size architectural space or even to on-site installations in real store environments.

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Self-chosen Colored Light Induces Relaxation

A. Johnson, & P. Toffanin

University of Groningen, Groningen, The Netherlands

Introduction

New technologies, in particular the availability of light emitting diodes (LEDs) in different colors, make it increasingly possible to integrate light into products and the environment. Moreover, research inspired by the discovery of short-wavelength sensitive retinal ganglion cells that are not involved in vision, but that do directly influence circadian rhythms, has shown that of different color lights temperature differentially affect circadian physiology and cognitive performance (e.g., Chellappa et al., 2011; Figueiro, Bierman, Plitnick, & Rea, 2009). In short, "color therapy" has taken on new meaning since the heyday of interest in its possibilities (e.g., Birren, 1950).

Psychological research on color, as such, has concentrated on color preference (e.g., 1941; Meerum Terwogt Eysenck, & Hoeksma, 1995) or the relation between color and emotion or mood (Levy, 1984; Meerum Terwogt & Hoeksma). Research on the relations between color and performance and color and mood has yielded mixed results. For example, whereas Knez (2001) and Boray, Gifford, and Rosenblood (1989) found no main effects of the color of environmental light on mood or performance, Knez and Niedenthal (2008) found that performance in a video game was better when the game world was lit by warm (reddish) as opposed to cool (bluish) light. In Knez and Niedenthal's study the reddish light was rated as more pleasant, leading the authors to suggest that the difference in performance between the conditions may have been mediated by pleasantness.

Our particular interest was whether exposure to colored light can induce a state of relaxation. To maximize any effects of color, participants were exposed to a near-Ganzfeld of color and were allowed to choose for themselves a color which they deemed relaxing. Relaxation was operationalized as alpha synchronization. Alpha activity is regular rhythmical activity of the brain in the frequency range from 8-12 Measured at the scalp using Hz. electroencephalography, alpha activity is usually associated with a no-task, nostimulation relaxed state, and is most evident when the eyes are closed. Alpha activity is reduced or eliminated when feeling anxious, when unfamiliar sounds are heard, or when concentration is high, and is interpreted as a state of relaxed awakeness without concentration or application of attention (Niedermeyer, 1997).

The possibility of inducing a relaxed state with colored light is an interesting one because of the proliferation of products that can be used to introduce colored light into the environment. To date, most of these products have been marketed as "mood lighting" rather than as a proven means of relaxation. A finding that some colors of light lead to more relaxation than others (and that observers are capable of determining which colors lead to a more relaxed state) would suggest that mood lighting could have therapeutic value.

Materials and Method

Twenty-three students and members of the University of Groningen community between 18 and 32 years old (mean = 21.1 years; 10 females and 13 males) volunteered to participate in the study. The study was approved by the local ethics committee and all participants gave their informed consent. The effects of colored light on relaxation and mood were assessed using the "Light ShowerTM" (Rozema, http://www.monartworks.nl/ thepalace.html; see Figure 1), a domed construction onto which light is projected while participants are seated on a chair with their heads and shoulders in the dome so that they experience what is essentially a Ganzfeld (a visual field without edges or contours; see Avant, 1965).

The Light Shower is 2.60 m high, and consists of a chair which can be raised into a cylinder with a diameter of about 1.5 m. The inside of the cylinder is lined with a dome made of opaque Plexiglas and extending 80 cm into the cylinder. The dome is provided with a "floor" of the same material as the dome, with a 35-cm hole cut into it through which the head can pass. Illumination is provided by RGB LEDs placed above and below the dome to create a uniform field of light. The brightness of the light depends on the color and intensity chosen by the observer, with a maximum of 500 lux. A computer program was used to present the full spectrum of colors. The intensity of the color could be changed by the observer using a computer mouse.



Fig. 1: The Light Shower

Mood was measured with the Positive Affect Negative Affect scale (PANAS; Watson, Clark, & Tellegen, 1988), a questionnaire with 10 items (adjectives) measuring negative affect and 10 items measuring positive affect. Participants were instructed to rate the degree to which each adjective described them at that moment in time using a scale of 1 (very slightly or not at all) to 5 (extremely). The experience of being in the Light Shower was assessed using an evaluation form with eight attributes (e.g., nice—unpleasant), each rated on a 7-point scale ranging from +3 to -3.

The EEG signal was recorded from Cz, Fz and Pz (the standard electrodes for measuring alpha activity) using a 19-Ag-AgCl electrode cap (Electro-cap International Inc., Eaton, Ohio, USA) and standard recording and filtering procedures.

After the EEG cap was fitted, participants (1) filled in the PANAS; (2) were subjected to measurement of baseline alpha (1 min with eyes open and 1 min with eyes closed); (3) entered the Light Shower to choose the that they found relaxing and colors energizing/not relaxing, respectively; (4) filled in the evaluation of the Light Shower and light quality questionnaires; (5) reentered the Light Shower where EEG was measured during 2.5 min exposure to the self-chosen relaxing color; (6) filled in the PANAS once more; (7) reentered the Light Shower where EEG was measured during 2.5 min exposure to the energizing/not relaxing color; and (8) were once more subjected to measurement of baseline alpha (1 min with eyes open and 1 min with eyes closed).

Results

Fifteen of the 23 participants chose a blue or green hue as relaxing; the remaining participants chose pink, purple, orange, or a neutral color. Only four participants chose green as energizing/not relaxing; the rest chose colors close to red/pink in the color spectrum. Three of the participants who chose red/pink colors as relaxing chose blue/green colors as energizing/not relaxing.

A repeated measures ANOVA with light condition (relaxing vs. energizing/not relaxing color) and electrode position (Fz, Cz, or Pz) as factors was conducted on alpha amplitude (see Figure 2). Alpha amplitude was consistently higher in the relaxing color condition than in the energizing/not relaxing color condition (F(1, 22) = 5.68, p = .02, $\eta^2_{partial} = .21$). Alpha amplitude depended on



Fig. 2: Alpha amplitude (in μ V) as a function of electrode position (Fz, Cz, or Pz) and light condition (energizing/not relaxing or relaxing color). Error bars are standard error of the means.

electrode position (F(2, 44) = 16.76, p < 0.01, $\eta^2_{partial} = .43$), but there was no significant interaction between electrode position and light condition.

To determine whether the difference between the relaxing light condition (which was measured first) and the energizing/not relaxing light condition might be attributable to order of administration, an additional analysis was carried out in which the preand post-exposure measures of alpha baseline and the alpha measured during the relaxing and the energizing/not relaxing light condition were compared (see Figure 3). Due to missing data two participants were excluded from this analysis. A repeated measures ANOVA with time interval (before exposure, relaxing light condition, energizing/not relaxing light condition, or after exposure) and electrode position (Fz, Cz, or Pz) as factors conducted on alpha amplitude showed a main effect of electrode $(F(2, 40) = 23.29, p < .01, \eta^2_{partial} = .54), a$ main effect of order ($\underline{F}(3, 60) = 3.39, \underline{p} = .02$, $\eta^2_{partial} = .16$), and no interaction. As shown in Figure 3, alpha tended to increase across the session, except in the energizing/not relaxing condition.

Both positive (t(22) = 7.52, p < .001) and negative (t(22) = 3.22, p = .004) affect as measured by the PANAS decreased after exposure to the Light Shower. Scores on the PANAS were somewhat higher on the



Fig. 3: Alpha amplitude as a function of electrode position (Fz, Cz, or Pz) and time interval during which alpha amplitude was measured. The dashed line is the average alpha amplitude across the three electrodes. Error bars are standard error of the means.

positive items (2.88 vs. 2.22 for the first and second measurements, respectively) than on the negative items (1.22 vs. 1.09, for the first and second measurements, respectively).

The ratings given to the adjectives used to evaluate the experience of the Light Shower were analyzed using separate two-tailed t tests. The Light Shower was evaluated as nice (mean = 1.38; t(22) = 5.41, p < 0.001), stimulating (mean = 0.71; t(22) = 2.38, p < 0.026), comforting (mean = 1.46; t(22) =5.42, p < 0.001), pleasant (mean = 1.38; t(22)= 6.15, p < 0.001), relaxing (mean = 1.38; t(22) = 4.78, p < 0.001) and calming (mean = 1.33; t(22) = 4.55, p < 0.001). No other differences were significant.

Discussion

This study focused on the intersection between entertainment and well-being in examining whether exposure to a pleasant, self-chosen light in the unique environment of a near-Ganzfeld could induce a relaxed state. The participants in this study were enthusiastic about the experience of being in the Light Shower used to administer the Ganzfeld of colored light, rating it as nice, stimulating, comforting, pleasant, relaxing, and calming. Evidence that people are able to select a color that relaxes them was found in the comparison of the alpha rhythm while in the relaxing light versus in the energizing/non-relaxing light: Alpha rhythm was higher in the self-chosen relaxing color as compared to a self-chosen energizing/not relaxing color.

Effects on alpha rhythm manifested quickly: Two and one-half min of exposure to the light was sufficient to see a significant difference in alpha amplitude for the relaxing and energizing/not relaxing color conditions. In itself, it is not surprising that alpha differences emerged quickly, as changes in alpha amplitude due to opening or closing the eyes typically emerge within 5 seconds (Niedermeyer, 1997). It might be argued that participants chose a preferred color as their relaxing color and a non-preferred color as the energizing/not relaxing color and that effects on alpha activity are mediated by color preference. However, Kawasaki and Yamaguchi (2011) recently showed that no asymmetries in alpha activity are found in a task of selecting a preferred color from one of two colors. To date, thus, there is no evidence that preference alone increases alpha amplitude.

One limitation of the study is that alpha for the relaxing color was always measured first. However, the fact that the pre- and postexposure measures of baseline alpha did not significantly differ suggests that order effects did not occur. Another limitation is that we cannot rule out that people's expectation that they would feel more relaxed when viewing the relaxing color than the energizing/not relaxing color may have influenced alpha activity. Current work being carried out in our laboratory will address this issue.

The research reported here suggests that people "know what's good for them" in that they were able to select a color which induces a relaxed state. This finding lends support to the idea that environmental light can be not only fun, but therapeutic.

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Poster

Experiencing Light: Review of Light's Impacts on Human Health

E. P. N. de Souza

UNICAMP, School of Civil Engineering, Architecture and Urban Design, Campinas, Brazil

Introduction

The light bulb's dissemination in 1879 initiated the study about photometric units, calculation methods and illumination's levels in order to ensure adequate illumination. During almost 20th century, this practice has adopted quantitative criteria instead of qualitative. The understanding that quantity does not necessarily imply quality is relatively new on the agenda of organizations dedicated to the study of lighting. This study aims to show the relationship between lighting and health by showing the concepts pointed by some researchers, checking how they understand the light's importance on building and also on human health: mind and body. The proposed study is part of a doctorate in which has been evaluated in practice/cientifically how light affects the hospital resident's health (psychological and physiological) from Hospital das Clínicas/ Campinas/Brazil.

Method

It was analyzed publications since 1920's to the present day, making use of datacenters like Medline, Science Direct, virtual collections from UNICAMP and specific books: architecture, medical specifications.

Result and Discussion

People feel healthy through the existence of many factors and every kind of edification has characteristics that may affect the occupants' health, like lighting conditions. According to Boyce (2006), the light effects in humans fall into three classes: i. the optical radiation that can be damaged when exposure to light for a long period; ii. the visual system and the possibility of darken and visual discomfort; iii. the circadian system and the sleep-wake cycle, cause light is essential also to the perception system. These four important items links our visual, task and human performances by considering their biological relation between: rhvthms: emotional variables (depression, anxiety, stress); hormonal levels (melatonin, cortisol); and physiological functions (sleep and neural performance). Proving that daylight can positively contribute to the human body helping to: relieve seasonal depression, quality improve sleep's and workers performance, regulate hormones. However, its absence results in negative consequences such as depression feelings, sleepiness, sadness, irritability, lack of interest of usual activities (FOSTERVOLD et al, 2010; SATER, 2010; BOYCE, 2006). Lighting becomes so one of the main determinants of environmental quality.

Conclusion

Those informations suggests the need of further development, which will only be effective by interdisciplinary, given its extreme complexity. There is a long path to follow in order to answer those questions and search for spatial conditions appropriate to our needs without interfering in our health.

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The Class A Color Designation for Light Sources

M. S. Rea, & J. P. Freyssinier

Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA

Introduction

Lighting manufacturers currently rely on two metrics to communicate to consumers the color qualities of light sources used for general illumination. Color rendering index (CRI) is used to describe how well the light source reveals, or renders, the colors of illuminated objects, and correlated color temperature (CCT) is used to describe the tint of the illumination provided by the light source. Those manufacturers interested in selling "high-quality color" illumination are at a disadvantage for two reasons: first, most consumers do not understand the current metrics used to describe color, and second, the current metrics are not entirely useful for predicting color perception. To the first point, most consumers are not lighting specialists and are only concerned with lighting occasionally (e.g., when purchasing or remodeling a home), so it is not economically feasible for the industry to undertake educational programs about color for consumers (Horner 2012). To the second point, a wide variety of studies have shown experimentally that CRI is poorly correlated with color preference (ASSIST 2010; CIE 2007; Narendran and Deng 2002), and more recently, it has been shown that people prefer "white" illumination, which is unrelated to CCT (Rea and Freyssinier 2012).

Proposed here is a simple way to inform consumers about the color-rendering properties of a light source and about the tint of illumination that is intuitive and immediately obvious, thereby obviating expensive educational programs, materials, and labels related to color. The proposed "class A color" designation bundles several metrics shown to be predictive of viewer color preferences, and the designation is intuitively obvious to consumers as one connoting a high-quality light source for color.

Fundamentals

The basic problem with CRI and CCT is that they are both based on orthodox colorimetry, a system of color measurement based upon color matching, not upon color appearance (CIE 1995, 2004; Rea 2000; Wyszecki and Stiles 1982).

Briefly, colorimetry is based upon the fact that any arbitrary spectral power distribution (SPD) can be matched perfectly to a unique mixture of three primary lights. By normalizing the amounts of the three primaries to sum to unity, it is possible to fully characterize the SPD of the matching light with the relative amounts of just two of the three primary lights. Thus, any SPD can be fully characterized in colorimetry with just a pair of chromaticity coordinates. Important for this discussion, however, is that chromaticity does not unambiguously describe color appearance. Indeed, light of a specific chromaticity may appear very different depending upon the person and the conditions under which the light is viewed.

Colorimetry is based solely upon the spectral characteristics of the light source. Apparent color is not. Color appearance depends not simply on the physical properties of the light but upon the visual infrastructure of the observer as well. Individuals with pre-retinal filters (e.g., cataract) or with only two cone photopigments will perceive а light differently than a young adult with all three photopigments. cone The amount of irradiance incident on an object also impacts its color appearance, even though the chromaticity is unchanged. Under very dim light levels, no hues (red, green, blue, etc.) can be perceived. Even at higher light levels where hue perception possible, is predict chromaticity does not color appearance. For example, the very same chromaticity can appear brown at low light levels and orange at high light levels. Most importantly, however, the spatial and temporal characteristics of the viewing conditions affect color perception. The same chromaticity can appear red or green, blue or yellow, depending upon the chromaticity placed next to it or seen prior to it. Therefore, it is inherently impossible to expect colorimetry, a color measurement system based upon color matching, to be predictive of color appearance.

Since both CRI and CCT are based upon colorimetry, they should not be expected to be, nor are they, predictive of color appearance. CRI is based upon the chromaticity shifts of eight (or 14) reference color chips when alternatively illuminated by a practical light source and by a reference light source. If there is a large net shift in chromaticity, CRI is low whether or not real objects (e.g., fruits and vegetables) illuminated by the practical source are seen as more appealing than when illuminated by the reference source. CCT is based upon the chromaticity of a practical light source with respect to the chromaticity of a reference source located on the line of blackbody radiation. Lights of exactly the same CCT but of different chromaticity can appear very different and none of them will necessarily appear "white," including the light with a chromaticity on the line of blackbody radiation.

Unfortunately, an accurate measurement system for color appearance under natural viewing conditions does not exist. Such a measurement system of color appearance would be inherently complex and distinctly non-linear. Cognizant of this problem, the industry has traditionally imposed a number of color appearance attributes onto the simple, additive system of colorimetry. These impositions on colorimetry have met with some, but not complete, success, as is the case for CRI and CCT. Proposed here for the "class A color" designation is a set of incrementally better, but still imperfect, impositions on colorimetry to better characterize the color-rendering properties and the apparent tint of illumination of a light source. By bundling these colorimetric metrics into a single color "class," consumers should be better able to choose light sources with "high-color quality" for general illumination.

Experimental results

"White" illumination

Chromaticities associated with blackbody radiation are universally used as the reference points for all light source types used for general illumination (ANSI 2001, 2011). Implicitly, chromaticities along the line of blackbody radiation are considered to be "white" even though the perception of "white" illumination had never been formally studied. Recent research has shown that perceptions of "white" illumination do not in fact lie on the line of blackbody radiation (Rea and Freyssinier 2011). Figure 1 shows the line of minimum tint from Rea and Freyssinier while observers viewed an empty box illuminated to 300 lx by sources of different chromaticities. It is important to note that there is a chromaticity of minimum tint at every CCT tested from 2700 K to 6500 K and these chromaticities usually look more alike (i.e., "white") than chromaticities of the same CCT on the line of blackbody radiation (Rea and Freyssinier 2011).

Subsequent research (Rea and Freyssinier 2012) has shown that when asked to view a scale model of a residential scene illuminated by two light sources of the same CCT, subjects preferred the one that provided "white" illumination and not the "yellow" illumination generated by incandescent sources (Figure 2).

It is important to point out that sources along the line of minimum tint in Figure 1 are not metamers. They look very similar (i.e., "white"), but they do not look identical. Theoretically, these sources should all be ones where the outputs from the neural channels in the brain that define hue are minimized. In other words, neural outputs from both the yellow-blue (y-b) and redgreen (r-g) color channels are minimized when subjects look at illumination provided by sources with chromaticities on the line of minimum tint in Figure 1. The "class A color" designation should help consumers



Fig. 1: Line of minimum tint and chromaticities of selected commercially available light sources used for illumination (after Rea and Freyssinier 2011). Three "class A color" sources that provide both "white" illumination and good color rendering are indicated with open triangles.



How much do you like this light source?

Fig. 2: Preference ratings for two light sources of the same CCT but different chromaticities when used to illuminate a scale model of a residential living room (after Rea and Freyssinier 2012).

choose "white" light for their homes, which they seem to prefer over "yellow" illumination from incandescent sources.

Color rendering

The industry has relied upon CRI as the primary metric for characterizing the colorrendering properties of light sources used for illumination since the 1960s. The developers of CRI, in particular Deane Judd (1967), pointed out that CRI could not be used as the only measure of color rendering. Rather, color rendering was a multi-dimensional construct whereby a single measure would not suffice to predict preference. Widespread use of solid-state lighting for illumination has made Judd's caution more acute. In fact, recent research has reinforced his early caution by showing that at least two-dimensions are necessary to predict user acceptance of color rendering (Davis and Ohno 2010; Rea and Freyssinier 2008, 2010; Smet et al. 2011; Žukauskas et al. 2011).

Observers prefer illumination that makes natural objects vivid without distorting colors. These responses are consistent with the inference that CRI can continue to serve as a practical, and certainly orthodox, measure of color fidelity, and that gamut area index (GAI) is a practical adjunct measure to CRI for characterizing the vividness of illuminated objects and color discriminability among illuminated objects (Rea and Freyssinier 2008, 2010). Neither metric alone will predict color preference, but combined they do. Several human factors studies with individuals from different cultural backgrounds have shown consistently that light sources with CRI equal or greater than 80 and GAI between 80 and 100 will meet the expectations of good color rendering. Figure 3 shows the results of these studies. Although there are subtle differences among cultures (e.g., people from Nordic countries prefer less saturated colors than those in South Asia), in general, two dimensions are better than one for predicting color preference. Therefore, a light source with a CRI equal or greater than 80 and GAI between 80 and 100 should meet the colorrendering requirements for a "class A color" light source.

Practical examples

Figure 1 also shows the chromaticities of a variety of commercially available light sources. Only three of those sources, two fluorescent and one HID, meet the proposed color" "class А designation. No commercially available "warm" light sources could be found that meet the "class A color" designation. Nevertheless, practical light sources with CCTs of 2900 K, 3000 K and 3500 K that do meet the "class A color" designation have been fabricated for laboratory purposes and could be developed for residential and commercial applications by manufacturers.



Fig. 3: Acceptability ratings of "warm white (WW)" sources of illumination with different color-rendering properties from five subject populations. The numbers in brackets correspond to the CRI and GAI values of the light source, respectively.

Conclusions

Consumers have limited knowledge and sophistication about the color characteristics of light sources. The current metrics used by the industry, CRI and CCT, cannot be readily understood by consumers, and more importantly, they are not predictive of the color characteristics they purport to measure. The proposed "class A color" designation for general illumination ("white" illumination with CRI 280 and 80 (GAI 2100) reflects a bundled set of metrics demonstrated to be predictive of color preference and should be readily understood by consumers. This simple method of communication should help manufacturers interested in selling, and indeed providing, sources of "high-quality color" general illumination to consumers.

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The Long-Term Evaluation of Electrochromic Glazing in an Open Plan Office under Normal Use: Project Outline

R. Kelly¹, J. Mardaljevic², B. Painter¹, & K. Irvine¹

¹ De Montfort University, Leicester, UK ² Loughborough University, Loughborough, UK

Introduction

Electrochromic (EC) glazing is emerging on to the market as a viable alternative to fixed transmittance glazing with traditional shading devices. In a double glazed EC window, one of the panes of glass has an electrochromic coating that enables it to change transmittance in response to a small applied voltage.

EC glazing has the potential to enable users to control glare from direct sun or bright patches of sky without the use of window blinds, giving users more access to daylight with all its inherent benefits. Users could benefit from having a view through the window throughout the day, even when the glass is fully tinted. Furthermore, EC glazing could reduce energy usage through a reduction of electric lighting use and a reduction of solar heat gain.

Research background

Previous research on the use of EC glazing in buildings has been based on scale models (Piccolo et al, 2009 & 2010), computer simulations (Sullivan et al, 1994; Moeck et al, 1998; Jonsson & Roos, 2010 and others) and full scale test rooms (Lee & DiBartolomeo, 2002; Zinzi et al, 2004; Rottmann et al, 2007). Several (Lee et al, 2006; Clear et al, 2006; Zinzi, 2006) have investigated the subjective effects of EC glazing on room occupants and have involved human participants. A recent study (Lee, 2012) investigated the effects of EC glazing in a functioning conference room in Washington DC, US. However, the usage patterns of a conference room (i.e. intermittent with highly variable occupancy) tends to confound attempts to make a systematic evaluation of user acceptance. Thus, in general, the literature review carried out to date indicates that there is a lack of research in real world settings, and essentially no research has been carried out over long-term monitoring periods (i.e. greater than six months).

This study aims to address these two important dimensions, by carrying out a case study into the effects of EC glazing in two existing and continuously occupied offices, the first installation of EC glazing in the UK. This paper describes the research questions to be addressed by the study and outlines some of the methodology. The installation of the EC glazing is planned for August 2012, and we will present our initial findings at the Experiencing Light conference in Eindhoven (November, 2012).

We believe that this study will have particular relevance for the building refurbishment sector. Refurbishment projects often involve changes that are primarily to the façade of the building. Contemporary buildings with highly glazed facades often suffer from problems of visual discomfort and solar gain. This in turn can lead to poor daylighting since the blinds are regularly left closed for extended periods (Van Den Wymelenberg, 2012). EC glazing could remove or at least reduce this problem by lessening the dependence on traditional shading devices such as blinds. To establish the potential of EC glazing in real world applications, the field trial needs to assess the direct impact on the visual and thermal environment as well as end user experience of the technology.

Research questions

The main research questions are as follows:

- 1. What are the practicalities of implementing this technology in a retrofit situation?
- 2. What is the optimum control strategy?
- 3. Can EC glazing without blinds provide visual comfort?
- 4. What is the effect of the EC glazing on subjective colour perception?

Proposed methodology

A case study will be carried out in two adjacent open plan offices in a university campus building. The rooms contain large southeast facing windows, and each room accommodates a small number of administration staff (seven in total). Figure 1 shows the interior of the two rooms before the EC glazing installation. Figure 2 shows the exterior façade of the two rooms, where it can be seen that the rooms share 3 windows between them, with a partition at the centre of the middle window. The monitoring period will be approximately 18 months, sufficient to encompass a variety of seasons and sky conditions.



Fig 1. The interior of the offices that will be used in the case study



Fig 2. The exterior façade showing the windows of the two case study rooms

The glazing product that will be used in the study is a double-glazed unit with an electrochromic coating on surface 2 (inside surface of exterior pane). The visible transmittance of the glass varies from 62% in the fully bleached state to 2% in the fully tinted state, with two intermediate states (20% and 6%). The glazing can be controlled automatically or manually. The control system can be zoned so that individual panes (or pairs of panes) can be controlled independently. The set-up can be summarised as follows:

Base case

- Switched fluorescent lighting
- Clear double glazing (poor condition)
- Window blinds

Test case

- Daylight-linked fluorescent lighting with occupancy sensing
- Electrochromic double glazing
- No window blinds

Reference case

- Daylight-linked fluorescent lighting with occupancy sensing
- Electrochromic double glazing switched to a continuous fully bleached state
- Window blinds

Preliminary monitoring is being carried out on the base case to provide some useful background data. The impact of EC glazing will be assessed by comparing the test case and reference case. The main study participants are the occupants of these rooms, and therefore will be exposed to both conditions. As such, this is a within-subject enquiry.

Ideally, the existing manually switched fluorescent lighting system would be changed in advance of the EC glazing installation to isolate the effect of the lighting system upgrade. However, in order to minimise disruption to the occupants, the lighting upgrade will occur at the same time as the EC glazing installation. A preliminary study revealed that the overwhelming concern that the occupants had regarding the luminous environment was with respect to the blinds and visual discomfort, rather than the artificial lighting. A settling-in period will allow occupants to get used to the new lighting system before beginning proper assessment of the impact of the EC glazing. Thus we believe that any 'confounding effect' of changing both the glazing and lights together will be minimised.

The lighting control system and EC glazing control system will be linked so that they can work together to provide control of the luminous environment. The monitoring campaign will capture both the response of occupants (subjective) and the impact on the physical environment (non-subjective).

Subjective measures

The subjective effects will be assessed using a combination of face-to-face interviews, questionnaires and diaries, which allow users to give regular qualitative feedback. The subjective assessment will capture the users' experience in terms of:

- (i) Visual comfort
- (ii) Thermal comfort
- (iii) Other subjective effects (e.g. alertness, wellbeing)
- (iv) User-friendliness
- (v) Colour perception

This assessment will give us an understanding of the effect of EC glazing on visual and thermal comfort, and on the wellbeing and alertness of occupants. The effect of the glazing in its tinted states on the perception of colour will be investigated in a separate experiment involving a different set of participants undertaking the Farnsworth-Munsell 100 Hue Test under controlled conditions and stable sky conditions.

In addition we will gain valuable feedback on occupants' experience of EC glazing, for example on the speed of response of the system, and the manual control interface.

Non-subjective measures

In parallel to the subjective assessments, a set of data will be gathered to capture the impact of EC glazing on the physical environment of the offices.

High Dynamic Range (HDR) imaging will be used to capture and quantify the luminous environment. Figure 3 shows a test HDR image taken in one of the case study rooms on an overcast day. It is not practical to locate the HDR cameras at the occupants' eye position, so the cameras will be positioned in view of the windows and will be compared with test images taken from the point of view of each occupant, to assess validity. Additionally, their when opportunities allow (e.g. weekends or when a participant is on leave), a HDR camera will be placed to match the occupant's typical viewing position. With a sufficient number of these 'opportunistic' HDR captures and simultaneous 'reference' HDR captures we hope to be able to infer the visual conditions (from the occupant's perspective) that triggered a manual override.

The software tool EvalGlare will be used to predict discomfort glare in the visual scene. These data will then be compared with the subjective experiences of the occupants.



Fig 3. A test HDR image taken in one of the offices that will be used in the field trial

Other measurements will be carried out to assess the thermal conditions and the status of various key items of equipment. To summarise, the key measurements are as follows:

- (i) Visual scene luminance (HDR)
- (ii) Room temperature
- (iii) Air conditioning status
- (iv) Heating status
- (v) Interior illuminance
- (vi) EC window control status
- (vii) Lighting control system status

In addition, external weather data will be accessed via a local weather station to give context to the interior measurements and assist with data analysis.

Preliminary data collection

A semi-structured interview was undertaken prior to any modifications to the offices' lighting and shading setup. The interview used a combination of scaled response and free text entries, and the questions were partly based on the questionnaire used in Clear et al (2006) and Osterhaus (2005). Four participants were interviewed, with the main aims as follows:

- 1. To gauge the occupants' current level of satisfaction with their office environment, in terms of visual comfort, thermal comfort and other relevant factors.
- 2. To gain insights into any particular problems experienced by occupants, e.g. recurrent glare problems at certain times of the day/year.
- 3. To learn about the participants' individual preferences, sensitivities and any relevant health conditions.
- 4. To enable the researcher and the participants to get to know each other, as part of the engagement process.

In addition, automated monitoring of the offices is being conducted in advance of the EC glass installation. This includes HDR captures, illuminance and temperature measurements. The data collected from this preliminary stage will provide useful background information on the conditions in the offices before the retrofit.

The findings of these preliminary data collection activities will be discussed at Experiencing Light 2012.

Summary

Based on physical characteristics alone – principally the wide dynamic range between clear and tinted states – EC glazing has significant potential to transform the way we use glass in architecture. This study will explore that potential by assessing the impact of the technology on end users in a real world setting. By measuring the subjective as well as the non-subjective effects in a typical office setting under normal use, a valuable data set is expected. One of the anticipated findings of this research will be to determine if occupants in a space with electrochromic glazing can control glare effectively without requiring the additional use of traditional shading devices such as blinds.

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Modeling of Comfortable and Energy-Efficient Light Distributions for an Indoor Environment

X. Wang, A. Jalalirad, T. Tjalkens, & J. P. Linnartz

Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

An indoor lighting system needs to offer adequate illuminance to satisfy multiple objectives simultaneously, such as visual comfort, visual performance and safety requirements. It has become a key challenge to increase energy efficiency without sacrificing the quality of light.

A popular and widely accepted idea is to divide the entire surface of the indoor environment into three kinds of areas, i.e. task area, surrounding area and other area. We provide enough illuminance for task area to enable users to perform their visual tasks; relatively low illuminance for other area to offer the visibility for curbs, stair edges, etc. and mid-ranged illuminance for surrounding area to avoid large variation of illuminance. In current European standard. the recommended illuminance for task area, surrounding area and other area are 500 lux, 300 lux and 60 lux, respectively [1].

However, several surveys have found that preferred light levels working in lower environments are often than recommended values [2][3]. Thus significant energy can be saved by adopting the lowest reasonable illuminance instead of the recommendations. Nevertheless, it is not easy to apply these results in an automatic control system because they don't give a formalized, computer-interpretable, mathematically unambiguous function that describes the relationship between visual comfort and illuminance. To solve this problem, this paper aims to propose a group of such functions which describes users' satisfaction for different illuminance and can be executed by an automatic controller.

This paper is organized as follows: Section 2 reviews several published experiment about user's satisfaction for different light levels. Section 3 proposes an example satisfaction function. Section 4 introduces two methods to choose the lowest illuminance requirement of a room and a method to realize a light pattern. Section 5 concludes the paper.

Visual comfort vs. illuminance over task area

Experiments [2] and [3] indicate that every individual *i* has a preferred light level ξ_i . Therefore for a group of people, their preferred light levels can be regarded as a statistical random variable Ξ with a certain distribution. Newham et al. asked 94 participants to set the desktop illuminance to the level that they like most and found that the preferred illuminance for most North American office workers is around 400 lux [2].

In 2001, Newsham conducted another experiment in which 47 participants were asked to set their desktop illuminance to their preferred light level [4]. Moreover, for each participant, another office worker was required to work together with the participant. After a day's work, the office worker was given an opportunity to increase or decrease the desktop illuminance (ΔL) according to his/her own preference. The result of both [2] and [4] are plotted in Figure 1 which suggests that Ξ is normally distributed. By maximum likelihood estimation, we found that the estimated mean value μ_{Ξ} is 429 lux and the estimated variance μ_{Ξ} is 151 lux.

Both experiments suggest that there exists a relationship between users' satisfaction and illuminance. According to [4], those office workers with small ΔL (-100 lux $\leq \Delta L \leq 100$ lux) had a significantly higher ratings of pleasure, lighting quality and general



Fig. 1: Frequency of illuminance ξ_i preferred by an individual and a fitted Gaussian probability density function $f_{\Xi}(\xi)$.

environmental satisfaction which means that ΔL is a good indicator for the user's opinion on the day's illuminance. Following [4], we divide the users' opinion into three categories, which are insufficient ($\Delta L <$ 100lux), satisfactory (-100lux $\leq \Delta L \leq$ 100lux) or excessive ($\Delta L <$ -100lux). The users' opinion of the 47 office workers are listed in Table 1 [4].

Table 1 User's opinion of their desktop illuminancefrom [4]

Interval (lux)	Insuff.	Satis.	Excess.
0 - 100	1	0	0
100 - 200	1	0	0
200 - 300	1	4	1
300 - 400	3	9	0
400 - 500	4	8	1
500 - 600	0	5	1
600 - 700	0	1	5
700 - 800	0	0	2

Thus we postulate the existence of a satisfaction function $P_i(x)$ which describes the satisfaction of individual *i* for a certain illuminance x that is uniformly distributed. A typical satisfaction function should have following three properties:

- 1. $0 \le P_i(x) \le 1$, for all x > 0 and every user *i*;
- 2. Larger value of $P_i(x)$ represents higher satisfaction;
- 3. $P_i(x)$ has a single peak at $x = \xi_i$.

It is reasonable to assume that individual *i* is satisfied with an interval of illuminance $\xi_{i\text{Low}} \leq \xi_i \leq \xi i_{\text{High}}$, where $\xi_{i\text{Low}}$ and ξi_{High} are the lowest and highest illuminance that satisfy individual *i*. Substantial amount of energy can be saved by setting the illuminace to $\xi_{i\text{Low}}$ instead of the European standard.

In order to determine $\xi_{i\text{Low}}$, we model the existence of a satisfaction threshold α_T . An illuminance *x* is regarded as "Satisfactory" by an individual *i* if and only if $P_i(x) \ge \alpha_T$. Thus the probability that a randomly selected person ranks x as "Satisfactory" is'

$$p(x \text{ is satisfactory}) = \mathbb{E}[p(P(x) \ge \alpha_T)],$$

which can be calculated from $f_{\Xi}(\xi)$ and other parameters in $P_i(x)$. Similarly, we can derive the probability that *x* is perceived as "Insufficient", "Satisfactory" and "Excessive". As verification, we can compare our theoretical outcome with experiment conducted by Balder in 1957 [5].

An example $P_i(x)$

Some people are only satisfied with a small range of illuminance while others are more tolerant, so preferably we introduce a parameter σ_i to describe the tolerance for illuminance of each individual.

Moreover, since different individual has different maximum satisfaction, a parameter to describe the maximum satisfaction of each individual is also necessary. According to Fechner's law [6], human eye senses brightness approximately logarithmically over a moderate range. Lacking a generally accepted model for $P_i(x)$, we propose an example $P_i(x)$ as

$$P_i(x) = \alpha_i e^{-\frac{(\ln x - \ln \xi_i)^2}{2\sigma_i^2}}$$

For a group of people, similarly as Ξ , both A and Σ are treated as random variables. Since brightness perception of human being is a very complex psychological and biological process which has not been well studied yet, we make a simplification that



Fig. 2: Results of our model (Illuminance) and Balder's experiment (Luminance) [5], with $a_T = 0.7$, the triangles, squares and circles are Balder's result, which represent "Too dark", "Good" and "Too bright", respectively

these three parameters are independent of each other. As discussed in Section 2, Ξ is normally distributed. However, for Σ and A, we cannot find any existing directly related experiments, so we postulate that Σ also follows a Gaussian distribution and A equals to one for all individuals. If more experiments or data are available, we can refine these assumptions.

With experimental data in Figure 1 and Table 1, we estimated the expectation and variance of Σ by maximum likelihood estimation. Then we can calculate the probability that x is ranked "Insufficient", "Satisfactory" and "Excessive". The result of both our model and Balder's experiment are shown in Figure 2 as a comparison and verification.

From Figure 2, it is clearly seen that the two results have a same trend. Moreover, a good numerical match between the two results is found if the reflectance is set to 0.95. Admittedly, this is a high value for any desktop surface. However, since Balder's experiment is conducted almost 60 years ago, many other factors such as the quality of light sources, living styles, etc. have changed, which may exist an effect on the result. Expectedly, both Balder's experiments and our theoretical result indicate that it is impossible to find a light level that satisfies everyone, unless personalized settings are applied which are dependent on the users' personal preferences.

Minimizing energy consumption

In this paper, an array of dimmable LEDs is used as light source. To minimize the energy consumption, a method based on convex optimization is applied to control the dimming matrix of the LED array. First the entire surface of the indoor environment is discretized into an M by N grid. Then the convex optimization problem is applied to find the optimum dimming matrix \mathbf{W} , as illustrated in Eq. (1).

$$\min \sum_{i=1}^{M} \sum_{j=1}^{N} I_{i,j}$$
subject to
$$\mathbf{I} \succeq \mathbf{I}_{\mathbf{r}} \qquad (1)$$

$$\min(\mathbf{I}_{t}) \ge \beta_{t} \overline{\mathbf{I}}_{t}$$

$$\min(\mathbf{I}_{s}) > \beta_{s} \overline{\mathbf{I}}_{s}$$

In Eq. (1), $I_{i,j}$ is the illuminance at grid point (i,j) which can be calculated from the dimming matrix **W** [7]; I_r is the minimum illuminance requirement; β_t , β_s are the requirements of uniformity w.r.t the average illuminance of task area I_t and surrounding area I_s , respectively. According to current European standard, $\beta_t = 0.7$ and $\beta_s = 0.5$.

 I_r can be determined by either the current European standard or a method that satisfies the majority of the users. As illustrated in Figure 2, at most we can satisfy 65.29% of the users by offering 430 lux for task area. Thus we set 400 lux as the minimum requirement for task area. The corresponding minimum requirement for surrounding area can be determined according to Table 2. Other area, the walking space between office desks, should be at least one-fifth the illuminance of the floor in adjacent areas. The detailed information of both methods is listed in Table 3.

Table 2 Relationship between illuminance of surrounding area and task area [7]

$I_t(lux)$	I_s (lux)
≥750	500
500	300
300	200
≤200	I_t

Table 3 Two methods to choose I_r

	Method 1 (EU standard)	Method 2
$I_t(lux)$	500	400
I_s (lux)	300	250
I_o (lux)	60	50

In order to compare the energy consumption of these two methods, we give a practical example. In this example, we consider a practical office of size 3 m by 7 m which accommodates three workers. Each of them sits behind a desk of size 0.75 m by 1.50 m, with a height of 1 m. The height of the ceiling is 2.60 m. The size of each task area is 0.5 m by 0.5 m. The lighting-on time is 11 hours per day. An array of Philips MASTER LEDspot D 7-50W 4000K PAR20 25D is used as the light source. The distance between every two LEDs in the array is 0.45 m.

The numerical result is listed in Table 4. It is clearly shown that about 20% of the energy is saved while 4% more of users are satisfied.

	EU Standard	Satisfying
		Majority
Energy	2.45	2.01
Consumption	kWh/Day	kWh/Day
$Ave(I_t)$	528 lux	422 lux
Users	61%	65%
satisfied		

Table 4 Numerical results of the two methods

Conclusion & Discussion

In this paper, we propose the concept of satisfaction function, which describes the

relationship between illuminance and the user's satisfaction with the lighting condition. Based on an example of our satisfaction function, we calculate the illuminance which can satisfy most of the users. Compared with the recommendations, about 20% of the energy consumption can be saved by adopting this illuminance strategy.

However, since the satisfaction function is a relatively new concept, only little experimental confirmation was available. Thus our modeling has been limited by postulated behaviors. Nonetheless a good match is found between experimental result and result derived from our model. Once more reference and experiments become available, we can refine our model to improve automatic light control system.

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Lighting Performance of Virtual Natural Lighting Solutions with a Simplified Image in a Reference Office Space

R. A. Mangkuto, M. B. C. Aries, E. J. van Loenen, & J. L. M. Hensen

Unit Building Physics and Services, Department of the Built Environment Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

Virtual Natural Lighting Solutions (VNLS) are systems that can artificially provide natural lighting as well as realistic outside view, with properties comparable to those of real windows and skylights. The benefit of installing VNLS in a building is the ability to use more space which has no access to daylight, i.e. located underground or faraway from the façade. VNLS is a new concept and does not yet exist in reality. The currently available virtual windows and skylights are considered not suitable for meeting the whole expectation, since they are only able to meet part of the natural light expectation (Mangkuto et al., 2011). Some user perception studies on view and light aspects of virtual windows have been reported by, e.g., IJsselsteijn et al, 2008, de Vries et al, 2008, and Shin et al, 2012.

In a bigger scope, it is intended to have an overview of the potential of VNLS system application in various building types. This will be done by using computational building performance simulation, which has the ability to predict the performance of such a non-existing solution. However, little is known about the technique to model an ideal virtual window, including a realistic outside view, to predict its potential for application in buildings.

The objective of this study is to describe the approach of modelling VNLS and using the Radiance lighting simulation package to compare the lighting performance of various VNLS configurations in a defined reference office space. Prior to incorporating a realistic view component in the performance assessment, a simplified image is included in the simulation.

The lighting performance is described in terms of the ability to meet the space availability demand, the illuminance uniformity on the workplane, and the ability to meet visual comfort demands, e.g. to produce minimal glare at predefined observer's positions in the given space. Space availability is defined as "the percentage of workplane (at height of 0.75 m from the floor) meeting a certain minimum illuminance criteria".

The building type discussed in this study is a reference office space with dimensions of 5.4 m \times 3.6 m \times 2.7 m ($L \times W \times H$). There are four vertical window configurations chosen from the earlier studies of Diepens et al (2000) and LBL (2010), see Figure 1. Each window configuration is modelled with a simplified viewed image on its surface. No real windows are present in the modelled spaces.



Fig. 1: Elevation view of the VNLS window configuration on the wall

Methods

Modelling

A VNLS surface is expected to resemble a real window, including the direct and reflected components. For this study, it is therefore modelled as arrays of light sources.

The VNLS in this study is modelled to fit two individual vertical windows, each with the size of 0.8 m \times 1.2 m (W \times H). Each light emitting areas in each individual window has the size of 0.05 m \times 0.05 m and resembling a blue sky. The sources have a beam angle, i.e. the angle between the two directions opposed to each other over the beam axis for which the luminous intensity is half that of the maximum luminous intensity, of 76°. At the lowest row, there are 4 (for configura-tions 1a and 2a) or 8 (for 1d and 2d) light emitting areas resembling a green ground surface. Since the windows' position in configurations 1d and 2d is higher, smaller number of green ground surface are used to make it invisible from the observer's position.

In order to model the directionality of the entering light, the sources at the highest row are tilted with a 40° angle (refers to vertical line) pointing downward. The sources at the row below are tilted with a 38° angle pointing downward, and so on with an interval of 2°. The "ground" sources are tilted with a 40° (for 1a and 2a) or 60° (for 1d and 2d) angle pointing upward. See Figure 2 for details.



Fig 2: Front and perspective views of the individual VNLS in configurations: (a) 1a and 2a, (b) 1d and 2d

The luminous intensity distribution of each light source is written in IES format file, based on the character of downlights with a large beam angle. The distributions have similar patterns, but different values, as shown in Figure 3. Each source in the highest row has maximum intensity of 14.8 cd at 0° angle. Each "ground" source has maximum intensity of 354 cd (for 1a and 2a) or 122 cd (for 1d and 2d, due to smaller size of individual source), with a similar pattern of luminous intensity distribution.



Fig 3: Polar diagram of luminous intensity of the light sources resembling the sky

Settings

In the given space, VNLS are put on the front wall (W 3.6 m × H 2.7 m). Frames of 5 cm wide are given at the perimeters of the windows. Reflectance values of the room's interior are: ceiling: 85%, walls: 50%, floor: 20%, door: 50%, window and door frames: 50%; all based on the IEA Task 27 reference office (van Dijk, 2003).

Three different observers' positions, namely A, B, and C, are defined at the eye height of 1.2 m above the floor. The view directions at positions A and B are parallel to the window plane, while C is directly facing the window plane, as shown in Figure 4.



For all simulations, ambient parameters in Radiance are set as shown in Table 1.

Parameter	Description	Value
-ab	Ambient bounces	4
-aa	Ambient accuracy	0.15
-ar	Ambient resolution	128
-ad	Ambient divisions	512
-as	Ambient super-samples	256

Table 1: Radiance ambient parameters

Assessment

The assessment for this study is based on the selected performance indicators of interest, which are:

- Space availability [%A]: percentage of workplane area (h = 0.75 m, equal size to the floor area) with illuminance ≥ 500 lx (typical criteria for office work). Calculation is performed for 1944 (= 54 × 36) points which are evenly distributed on the workplane. The %A is the percentage of the number of points with illuminance ≥ 500 lx, compared to the total number of points.
- Uniformity $[U_0]$: ratio between the minimum illuminance to the average; based on the defined calculation points.
- Glare indices: since it is not a priori clear which glare indices are most suited to use for VNLS, we calculate all potentially relevant ones, i.e. DGP, DGI, UGR, and CGI, in Evalglare. The results are also normalised as suggested by Jakubiec and Reinhart (2012) to determine the "probability of discomfort glare", by multiplying DGI value with 0.01452, and multiplying UGR and CGI values with 0.01607.

As a mean of comparison, the VNLS in all configurations are replaced with real windows (double clear glass 6 mm, transmittance 88.5%) under a CIE overcast sky condition giving approximately the same average window luminance (3200 cd/m²). The same assessments are then performed.

Results

The space availability, uniformity, and probability of discomfort glare for all configurations and positions with VNLS and real windows are summarised in Tables 2 and 3, respectively.

Table 2: Summary of %A, U₀, and probability of discomfort glare for all configurations and positions in VNLS scenes

Con.	%A	U_0	DGP	DGIn	UGR _n	CGI _n
1a, A			0.25	0.23	0.37	0.40
1a, B	29.3	0.28	0.21	0.19	0.32	0.35
1a, C			0.27	0.33	0.45	0.47
1d, A			0.20	0.12	0.26	0.27
1d, B	25.4	0.26	0.20	0.16	0.29	0.31
1d, C			0.26	0.31	0.44	0.45
2a, A			0.21	0.17	0.32	0.34
2a, B	32.2	0.31	0.21	0.21	0.31	0.34
2a, C			0.27	0.34	0.45	0.47
2d, A			0.19	0.12	0.23	0.26
2d, B	26.2	0.29	0.20	0.19	0.28	0.31
2d, C			0.26	0.33	0.43	0.45

Table 3: Summary of %A, U_0 , and probability of discomfort glare for all configurations and positions in real windows (overcast sky) scenes

Con.	%A	U_0	DGP	DGIn	UGR _n	CGI _n
1a, A			0.24	0.21	0.35	0.39
1a, B	27.9	0.16	0.21	0.19	0.31	0.33
1a, C			0.26	0.31	0.43	0.45
1d, A			0.22	0.17	0.32	0.33
1d, B	25.0	0.24	0.20	0.16	0.28	0.31
1d, C			0.26	0.30	0.42	0.44
2a, A			0.22	0.26	0.36	0.39
2a, B	29.5	0.15	0.21	0.22	0.32	0.34
2a, C			0.26	0.33	0.43	0.45
2d, A			0.21	0.23	0.33	0.35
2d, B	25.1	0.19	0.20	0.20	0.30	0.32
2d, C			0.26	0.32	0.42	0.43

To give a visualisation of the simulated space, the rendered images with their corresponding luminance false colour map at the three positions in configuration 1a are shown in Figure 5.



Fig. 5: Rendered image of the space with the corresponding luminance false colour map in configuration 1a, viewed from (a) position A, (b) position B, and (c) position C

Discussion

Based on the simulation results, the space availability obtained is 29% in VNLS configuration 1a, 25% (1d), 32% (2a), and 26% (2d). These values are slightly larger than those obtained in real windows scenes. The uniformity in all VNLS scenes ($0.26 \sim 0.31$) are also larger than those in real windows scenes ($0.15 \sim 0.24$). The glare indices are largely determined by the observer position. Position C experiences the worst glare perception. In the configurations 1d and 2d, where the VNLS are raised up to the ceiling, the glare perceptions are better than those in configurations 1a and 2a.

By definition, DGI and DGP may be the better indicators, since VNLS is meant to emit virtual daylight. However, viewed from position C (Figure 5c), the VNLS surface on average gives luminance of 3200 cd/m^2 , while the immediate surrounding wall surface gives around 35 cd/m². This indicates a risk of glare, which is underestimated in both DGI and DGP calculations. The probability of visual discomfort results show that UGR and CGI values are found in the middle range, and

in no case are larger than 0.50, suggesting that glare problems can be expected in less than 50% of the time. In general, the question to find the most appropriate glare indicators for VNLS remains open until it is validated with users experiment. Nevertheless, the results indicate that the probabilities of discomfort glare in VNLS scenes are comparable to those in real windows scenes.

In this simulation study, we model a VNLS configuration composed of light emitting sources with the size of 0.05 m \times 0.05 m. It shows the possibility to model the direction of light from the "ground" to the ceiling and from the "sky" to the floor. We also show that the simulated VNLS can give generally larger space availability and uniformity, compared to similar scenes with real windows, while main-taining the discomfort glare comparable to the real windows scenes. In reality, the VNLS configuration can possibly be built by employing arrays of small light sources such as LEDs. Alternative configurations and source parameters will be studied to further improve the visual comfort characteristics.

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The Perception of Central London by Night

D. Del-Negro

UCL Bartlett School of Graduate Studies, London, United Kingdom, diana.del-negro.09@ucl.ac.uk

Introduction

Several studies (Downs, 1977; Golledge, 1999; Lynch, 1960; NATO, 1987) suggest that the legibility of a city and the ability of successfully finding the way rely in memorizing and recognizing certain visual patterns, or urban elements. In his work, Lynch (1960) isolated five distinct elements which act as reference points to read and have a sense of orientation in an urban environment.

Landmarks are considered (Downs 1973, 1977; Golledge R. G., 1999; Lynch, 1960) to be a fundamental component of the mental representation of a known environment, or cognitive maps. Spatial knowledge and efficient navigation rely on detecting and recognizing landmarks, because these act as references that enable to travel from one point to another. A traveller can therefore follow a sequence of landmarks and be able to make choices at decision points. Landmarks can also help to organize large scale spaces, and may provide references with which to calibrate distances and directions (Sadeghian & Kantardzic 2008).

A landmark is characterized for being prominent attracting and attention. Characteristics that contribute to the visual saliency or singularity of an object include having a sharp contrast with the surroundings and having memorable or unique features (Lynch, 1960; Sadeghian & Kantardzic, 2008). Visual contrast may be achieved through a difference in shape, colour or luminance. But, according to Sorrows & Hirtle (1999), a landmark may also be acknowledged due to its underlying meaning, or structural salience.

However, elements visually salient under natural light may not be seen as landmarks at night, where lighting conditions are necessarily different. Artificial light, or its absence, may reduce an object's visual saliency in different ways. It may break its luminance or colour contrast with the background, for example if it is dimly lit or lit by a poor colour rendering source, or with a colour similar to the surrounding environment. Additionally, the shape of an element may also be transformed through lighting, thus modifying its conspicuity, for example if the element is only partially lit.

Research on urban legibility, has been mostly developed considering only day lighting conditions. However, as described, objects and environments can be quite different during the day and night-time. In fact, elements acknowledged as landmarks during the day may not be recognized as such during the night, and new landmarks may emerge, as studies by Yuktadatta (2002) and Winters, Raubal, & al. (2004) have shown. Thus, it can be deduced that artificial lighting transforms the appearance and perception of the cities, and may influence its legibility and way finding.

The main objective of this paper is to evaluate how the perception of the most recognizable elements of a city can be modified during the night. It will be hypothesized that the most recognizable landmarks of a city may lose visibility at night, and perceptual hierarchies may become distorted.

The exercise follows a methodology similar to that developed by Kevin Lynch (1960), applied to London's city centre, with an added night-time dimension and a luminance pattern assessment.

It is expected that the results may contribute to complete Lynch's findings and to better understand the role of lighting in urban perception and legibility.

This study is part of a larger research project, involving the analysis of other cities and other stages of Lynch's methodology (1960). It is being replicated in Lisbon, a city



Fig. 1: The fifty most distinctive elements of London in decreasing order

with a different culture, light, morphology, urban shape and architecture. In the long term, the comparison between both cities' results should provide interesting clues, about the effect of artificial and natural light in the perception of similar urban elements, located in different contexts.

Methodology

The experiment comprised three stages, partially following Lynch's methodology.

In the first stage, thirty volunteers were questioned individually, in a closed room. Subjects were all residents in London, aged between 20 and 65 years old. An equal number of males and females were interviewed.

Among other questions, people were asked to draw a map of what they considered to be London's centre and its main elements. They were also asked to name and describe what they thought were the most distinctive and recognizable elements of the city centre. Afterwards, they tried to explain which characteristics made these elements distinctive.

The results of the interviews provided one hundred and sixty eight distinctive elements, which could be classified under Lynch's nomenclature as *landmarks*, *nodes*, *paths*, *edges* and *districts*. This number resulted from the account of elements drawn and described as distinctive. The sum of the total of times these were mentioned and drawn allowed them to be ranked in a certain order. The highly ranked element was the river Thames, which was mentioned and drawn 33 times. There were dozens of elements which were only mentioned or drawn once, making them the lower ranked elements. Only the first fifty highly ranked elements were considered for the next stages of the study.

In stage two, each element was photographed in agreement to what the subjects described as being its most recognizable features. Consequently, for example, Hyde Park was pictured from an angle which included the lake and the horse track.

Two pictures were taken for each element: One during the day and another during the night. Both were taken exactly from the same position. Additionally, luminance pattern was measured in order to later have an objective assessment of the luminous environment.

The third and final phase of the experiment involved presenting subjects with the photographs in an interview, following again Lynch's methodology. This group was composed by volunteers who declared having a good knowledge of central London, half of which had participated in the first part of the experiment. The main differences to the methodology described in "The image of the city" is that the city is additionally portrayed at night, and that the photographs only represent fifty carefully selected places, instead of systematically covering the entire city.

The interview consisted in presenting London's day-time photographs to fifteen subjects, and the night-time pictures to a different group of fifteen people. Two photographs from Lisbon were inserted in each collection as a control. The interviews were performed in a closed room, individually, and consisted of three tasks. First, the individual was asked to classify the pictures in whatever groups seemed natural. Secondly he was asked to identify as many images he could and to describe which clues he used to do so. Next, he was asked to



Fig. 2: Graphic representing the day and night-time percentage of unidentified and misidentified elements.

display the photographs in a large table as if he was placing them in the proper position in a large map of the city. Finally, he was presented with either the day or night-time photograph version of those elements he was not able to recognize.

Results

The analysis of the data provided by the experiment consisted in appraising the level of recognition of each element for day and night-time responses. It also comprised comparing the features described as being the most significant clues that enabled the recognition of each element. Finally it entailed examining the order in which these clues were described.

The recognisability of each element was assessed by evaluating which was the main element recognized in the photograph, the number of times the element was correctly identified and the level of certainty of this identification, that is, if subjects were sure or unsure of their answers.

The results showed that the highly ranked elements were also the most recognizable elements during the day, but not necessarily during the night. Oxford Circus, was however an exception. Ranked as the sixth most distinctive element of London, its daytime image was expected to be recognized by all participants. However, in day interviews 27% participants did not recognize it, against 7% in its night version. This result seems to be related to the perception of the existing buildings' curved shape, which was found to be one of Oxford Circus' most recognizable features. The curved shape is more evident at night than day due to the high luminance contrast between the top edge of the buildings and its background, almost non-existent under day light.

As expected, night environments with low luminance contrast became almost unrecognizable in the night. Hyde Park, which was considered the third most distinctive element of London, was recognized by all subjects, but became totally unrecognizable at night. A quarter of the inquired stated that the element in the picture was the river, after perceiving reflected lights on a body of water (the serpentine lake). The Gherkin, mostly recognized due to its shape, was always correctly identified under day lighting, but became imperceptible to almost all participants faced with its night image. Those working in the City were the only ones able to identify it, even if unconfidently, by noticing the red aircraft warning lights that line the building. Additionally, the main day--time recognition clues for the City of London were both the Gherkin and Saint Paul's Cathedral, but at night, subjects failed to acknowledge any other elements apart from the Cathedral.

There were elements which were consistently confused with others at night. It was the case of the Natural History and the British Museums, respectively confused with the National Gallery and the Houses of Parliament or Westminster Abbey. The British Museum and the National Gallery main recognizable features are similar, having both an exterior portico. The main differentiator factor stated by subjects after being faced with the day version of the photograph was the fact that the British Museum has a recessed façade, which

appeared flat under artificial lighting. Additionally, the space in front of the building became too dark to identify.

Sixty per cent of the participants confused the night-time photograph of the Natural History Museum with the Houses of Parliament or Westminster Abbey. The main reasons for this result seem to be related to the similar architecture style between the two buildings, and to the colour appearance of the Museum's façade. The façade was described as white and blue during the day, but yellow at night. Being lit by RGB LEDs, tuned to white, it is possible that the colour rendering may be affecting perception.

Another interesting difference between day and night interviews was the order in which the recognition clues were described, suggesting that perceptual hierarchies may be transformed under artificial lighting. For example, when observing the day-time photograph of Tate Modern, which included the Millennium Bridge, subjects recognized first the art museum, due to its distinctive chimney, and secondly the bridge. However, in the nigh-time photograph, the unlit became invisible. chimney As а consequence, the primary element the participants recognized was the brightly lit Millennium Bridge, and then assumed that the almost unlit building in front had to be Tate Modern.

The Waterloo Bridge, which was recognized by less than half the participants during the day, was recognized by more than seventy per cent subjects at night, mainly due to the unusual pink colour and brightness of the National Theatre façade, located next to it. The National Theatre was the primary element recognized at night, after which the bridge would be identified, inverting the daytime hierarchy.

Expectation also played an interesting role. Places expected to be filled with people, such as Covent Garden or Soho were less recognized when presented empty, such as in Soho's day-time image. Some subjects who confused the Natural History Museum with the Houses of Parliament pointed Big Ben and a statue, which did not exist, because they expected to see it near the Parliament. Others found difficult to recognize the Tower of London because they expected to see Tower Bridge next to it.

The importance of distant lit landmarks seems to gain importance at night, to provide geographic orientation. Although most of the parks are in almost complete darkness at night, the existence of distant brightly lit landmarks, such as the BT Tower and Centre Point in Regent's Park, and Victoria Memorial in St James's Park, enabled these parks recognition.



Fig. 3: Images of Saint Pancras Station. From the left to right: day-time image, night-time image and luminance pattern image generated by imagelum software from measurements collected in the field.

Conclusions

The study confirmed that luminance and colour contrast affect the way highly recognizable objects are perceived at night. It suggests that it may enhance, create new landmarks or "erase" them. Also, the transformations introduced by lighting in an object's shape and colour appearance may help or compromise its correct identification, and expectations may facilitate or hamper recognition. Distant lit landmarks, which may not be recognized as such during the day, gain particular importance at night, for recognizing and geographically positioning low luminance environments.

In conclusion, the experiment showed that the image and perceptual hierarchies of some of London's main landmarks becomes transformed at night and not always in a positive way. As a consequence subjects were less able to place them in their correct geographic position, suggesting cognitive mapping may also be affected at night. However, further investigation is needed to better evaluate the consequences on legibility and orientation in the city.

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Calibrated Personal Light Exposures as They Might Affect Melatonin Suppression in Different Populations

M. G. Figueiro, M. S. Rea, & R. Hamner

Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA

Background

In mammals, melatonin is synthesized by the pineal gland at night and in darkness. Studies with nocturnal rodents have shown that a reduction in melatonin can enhance tumor growth (Blask, Dauchy, & Sauer, 2005). Since light can suppress melatonin at night, concerns have been expressed in the literature about light at night (LAN) as a potential causative agent for breast cancer in humans (Stevens et al., 2007).

Optical radiation incident on the retina will suppress melatonin synthesis if the light levels are sufficiently high and the durations are sufficiently long (Figueiro, Lesniak, & 2011; Lewy, Wehr, Rea. Goodwin, Newsome, & Markey, 1980; Rea, Figueiro, Bierman, & Hamner, 2011; Rea, Figueiro, Bullough, & Bierman, 2005; Zeitzer, Dijk, Kronauer, Brown, & Czeisler, 2000). The amount and duration of light exposure necessary to suppress melatonin production is species specific. The circadian systems of nocturnal rodents are several orders of magnitude more sensitive to light than that of humans. The spectral sensitivities of species also differ. Rodents are, for example, highly sensitive to ultraviolet radiation while humans are not at all sensitive to radiation in this region of the electromagnetic spectrum (Amir & Robinson, 1995; Benshoff, Brainard, Rollag, & Lynch, 1987; Bullough, Rea, & Figueiro, 2006).

To properly consider LAN as a potential causative agent for breast cancer, it is necessary to, first, properly characterize light as a stimulus for the human circadian system and, second, to measure calibrated personal light exposures in populations that might be at risk for breast cancer (Figueiro, Rea, & Bullough, 2006; Rea, Brons, & Figueiro, 2011). The goal of the present study was to examine personal calibrated light exposures in different groups of participants and relate them to predictions of how they might impact melatonin production. All participants had worn the Daysimeter, a personal circadian light meter, for a period of five to seven days, depending on the experimental protocol (Bierman, Klein, & Rea, 2005).

Methods

Instrumentation

The Daysimeter measures and records a person's light exposures and activity levels during their normal daily routine (Bierman et al., 2005). Since light must reach the eye to be effective for the circadian system, the Daysimeter is designed to measure light in the plane of one cornea. The Daysimeter is calibrated in terms of photopic illuminance (lux), circadian illuminance (CL_A), and the absolute sensitivity of the human circadian system (CS). CL_A is a measure of circadian effective light, and it is based on the model of phototransduction by Rea et al. (2011, 2005). The values of CL_A are scaled so that 1000 lux of CIE Illuminant A (incandescent source at 2856 K) is equivalent to 1000 units of CLA. CS values are transformed CLA values, and correspond to relative melatonin suppression after one hour of light exposure for a 2.3 mm diameter pupil during the midpoint of melatonin production (Rea, Figueiro, Bierman, & Bullough, 2010). Since CS is defined in terms of the circadian system's input-output relationship, including threshold and saturation, it is considered a better measure of the circadian effectiveness of light than either lux or CL_A.

Participants

We reanalyzed data from four different studies in which participants wore the Daysimeter for at least five consecutive days: 24 young adults age 18-30 years (Sharkey, Carskadon, Figueiro, Zhu, & Rea, 2011), 22 school teachers (Rea, Brons, & Figueiro, 2011), 22 8th graders (Figueiro, Brons, Plitnick, Donlan, & Leslie, 2010), and 77 rotating- and day-shift nurses (Miller, Figueiro, Bierman, Schernhammer, & Rea, 2010). Participants had been instructed to keep their normal schedules while participating in the study.

Procedures

Participants in every study were instructed to wear the Daysimeter at all times except when sleeping or bathing, and to place it next to them when it was not being worn. All subjects were trained to use the device by a member of the research team, and written instructions were left with each subject. Subjects were also instructed to keep a sleep log and report when they wore the device as well as their wakeup and bedtimes.

Results

Table 1 shows the mean evening (four hours before bed) and the mean morning (four hours after rising) light exposures for the different groups. It should be emphasized that the evening and morning values can occur both early and late in the day for rotating nurses. From the Daysimeter data, we calculated mean lux, CL_A, and CS exposure levels. Log₁₀ transforms of the photopic and CL_A values are included because of the highly skewed distributions of recorded light exposures; brief exposures to extremely bright light (e.g., sunlight) dominate the arithmetic mean values. The \log_{10} transform of the values is probably more representative of the central tendency in light exposures than the arithmetic mean.

Discussion

Several studies have postulated that exposure to electric LAN poses health risks because it is sufficiently bright to suppress melatonin or to disrupt our circadian rhythms (Stevens, 2005; Stevens & Rea, 2001; Stevens et al., 2007). However, very few data have been reported concerning actual light exposures in living and working environments during night and day. Gooley et al. (2011) showed that an 8-hr exposure to < 200 lux at the cornea of a 4100 K light source resulted in significant suppression of evening melatonin in the laboratory. Although no real-life light measurements were presented by the authors and they did not utilize a photometric instrument calibrated in terms of the spectral sensitivity of the human circadian system, they postulated that 60 to 180 lux at the cornea (which was referred to as < 200 lux condition) is representative of room lighting that individuals are typically exposed to in their homes in the evening. Depending upon the spectral power distribution of the source, 200 lux at the cornea from a 4100 K source is associated with a CS value of between 0.15 and 0.19. The present data suggest, however, that average evening light exposures by various populations do not reach this level in any population, including rotating-shift nurses who, among the groups examined

	Lux	Lux	Loglux	Loglux	CL _A	CL _A	LogCL _A	LogCL _A	CS	CS
	morning	evening	morning	evening	morning	evening	morning	evening	morning	evening
Young	772	38.2	2.00	1.22	1650	34.3	2.02	1.17	0.193	0.046
adults (24)	±188	±4.3	±0.06	±0.06	±438	±3.6	±0.06	±0.05	±0.015	±0.005
Teachers	373	40.4	1.94	1.07	478	44.1	1.88	0.97	0.172	0.036
(22)	±80	±9.9	±0.05	±0.06	±105	±14.5	±0.06	±0.07	±0.013	±0.006
8 th Graders	268	63.0	2.04	1.19	305	78.4	1.96	1.13	0.184	0.046
(22)	±25	±19.6	±0.04	±0.08	±54	±30.7	±0.03	±0.08	±0.006	±0.008
Day-shift	296	73.9	1.49	0.94	408	35.8	1.30	0.79	0.109	0.029
nurses (33)	±50	±16.9	±0.04	±0.05	±173	±11.1	±0.06	±0.04	±0.011	±0.004
Rotating-shift	277	104 .0	1.37	1.09	414	135	1.35	1.06	0.114	0.066
nurses (44)	±56	±13.7	±0.04	±0.06	±103	±22.4	±0.04	±0.05	±0.009	±0.006

Table 1: Mean and standard errors of the mean (±) morning and evening light exposures for different populations



Fig. 1: Day-shift and Rotating-shift 24-hr CS and activity profiles. The data for every rotating-shift and every day-shift subject were averaged in one hour periods to create a 24-hr profile representing the average 24-hr light/dark and rest/activity patterns for each of the groups. CS levels were set to zero and activity levels were set to the minimum activity level recorded by the device during sleep periods. Any periods of inactivity exceeding 30 minutes that occurred outside of sleep periods were removed since those represent probable non-compliance.

here, are known to be at higher risk for breast cancer. The mean CS values ranged from 0.03 to 0.07, suggesting that their evening light exposures would result in suppression values that were below 7%. Figure 1 shows the average light and activity profiles of dayshift and rotating-shift nurses from Table 1. What is most apparent in this pair of plots is the lack of consistency in the light/dark and activity/rest patterns for rotating-shift nurses as compared to the day-shift nurses. Clearly too, Figure 1 shows that rotating-shift nurses, unlike day-shift nurses, are exposed to circadian-effective light throughout their biological night that could potentially suppress nocturnal melatonin.

The significance of these light exposures for health outcomes is not known, but recent

studies suggest that LAN as actually experienced at night on rotating-shift *workers* may not be the root (or the only) cause of low melatonin levels and, by extension, poor health outcomes in this population. Dumont, Lanctôt, Cadieux-Viau, and Paquet (2012) measured ambulatory light exposure and 24-hr melatonin excretion [6sulfatoxymelatonin (aMT6s)] in 13 full time rotating-shift workers working both nightand day/evening-shift periods. The authors found no difference in total 24-hr aMT6s excretion between the two working periods. were Moreover, light exposures not correlated with aMT6s levels excreted during the night of work. The authors did find, however, that the measured light exposures were negatively correlated with total 24-hr aMT6s excretion when they were working the night-time period. As the authors suggest, circadian desynchrony may have attenuated melatonin production and thereby induced the overall lower levels of melatonin excretion. In another study, Peplonska et al. (2012) examined aMT6s in 354 nurses and found midwives and no significant differences in aMT6s concentrations between women working rotating shifts and those working day-shifts. However, women who reported working, on average, eight or more rotating night-shifts per month did have significantly lower aMT6s concentrations than those who worked fewer nights per month.

The measured light exposures (CS) presented in Table 1 and Figure 1 appear to be consistent with the results of Dumont et al. and Peplonska et al. Namely, the circadian-effective light exposure levels are relatively low during the working nights for rotating-shift nurses, but because rotating-shifts create an inconsistency in the light/dark exposure (and activity/rest) pattern over many days and weeks, circadian dysynchrony can occur, resulting in lower total melatonin concentration levels.

The data presented here further help our understanding of light exposures in different populations. These data are very rich and offer many opportunities for further analyses that are just beginning to be pursued, including an investigation of the level of circadian disruption experienced by these various populations. In general, tools like the Daysimeter now make it possible to measure real-world circadian light exposures and to determine levels of circadian entrainment in the field. These measurements can also help provide insights into possible improvements in the environmental lighting conditions that could minimize maladies associated with disruption of the circadian system.

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Poster

The Experience of Ambient Light from Common Light Sources with Different Spectral Power Distribution – Light Emitting Diodes (LED) vs. 3-Phosphorus Fluorescent Tubes (T5)

T. Govén¹, & T. Laike²

¹ Fagerhult, Lighting Technology, Stockholm, Sweden ² Lund University, Faculty of Engineering, Lund, Sweden

Abstract

This abstract shows a comparison of the subjective experience between indirect light from LED and T5-fluorescent tubes at different ambient light levels in an indoor office environment. The test was conducted as a laboratory study containing 50 subjects, ranging from 18 to 68 years of age. The experience of the environment was measured by using semantic scales. Furthermore the experience of the lighting situation was conducted by means of semantic scales.

The aim of the present study was to investigate whether ambient light in the normal field of view was experienced as brighter at luminance levels of 100 and 300cd/m² on the walls comparing LED Fortimo vs. T5 fluorescent tubes at 4000K.

Two hypotheses were stated:

- Ambient light from the LED may be experienced more bright than from T5
- Ambient luminance levels up to 300cd/m² may not be experienced as glaring. *Results were investigated in terms of:*
- Room appearance
- Experienced brightness
- Experienced lighting quality
- Biological aspects hormone analyses

Results

Results show that the experienced brightness from LED was significant higher in both ambient light levels and there was also a tendency to experience light quality as better from LED as better than from the T5 tubes at 100 cd/m².

Room appearance

The two test rooms in the two different ambient lighting conditions were perceived quite neutral. The rooms were perceived neither pleasant nor unpleasant, neither complex nor much unified and no significant differences where found between perceptions of the light sources at same CRI and CCT.

Experienced brightness

In general the results show that the experienced brightness from LED was significant higher in both ambient light levels than from T5 tubes. Differences in experienced light intensity between T5 4000K vs. LED 4000K, CRI=80 at different ambient light levels, p=.034. Furthermore, the difference in brightness increased at the highest ambient light level.





Experienced lighting quality

There was a tendency to experience the light from LED as better than from the T5 tubes (p=.07) at 100cd/m2. However, the lighting quality was reduced for LED at the higher ambient light level, although not significant.



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Getting Close in the Dark: Darkness Increases Cooperation

L. Werth¹, A. Steidle², & E. Hanke¹

¹ Chemnitz University of Technology, Chemnitz, Germany ² University of Stuttgart, Stuttgart, Germany

Introduction

Aspects of our physical environment, such as temperature and space, can influence social contact by evoking bodily and perceptual experiences that signal social distance or proximity and can trigger compensatory behavior (Bargh & Shalev, 2011; IJzerman & Semin, 2009; Kolb, Gockel, & Werth, 2012; Williams & Bargh, 2008). Darkness also changes social perception and behavior but it is rather unclear how (Baron et al., 1992). The present paper addresses this question from a social distance perspective (Liberman, Trope, & Stephan, 2007).

First, darkness and dim lighting conditions impair visual perception, particularly the perception of details, and recognition of other individuals. The lack of detailed information about another person increases one's perceived distance (Trope & Liberman, 2010) and is assumed to evoke a feeling of isolation and anonymity (Page & Moss, 1976; Zhong, Bohns, & Gino, 2010). Accordingly, it has recently been demonstrated in a series of IATs that darkness is conceptually associated with psychological distance, including social distance (Steidle, Werth, & Hanke, 2011). In sum, darkness can be understood as an environmental condition associated with social distance.

Second, humans generally strive to be close to other humans (Baumeister & Leary, 1995), especially in situations evoking social distance and the danger of social isolation (Williams, 2007). Hence, we argue that darkness, as a sign of social distance, should enforce strivings for social closeness. In support of this assumption, several studies have shown that experiencing fear in the dark increases people's inclination to affiliate with others (Darley & Aronson, 1966). Children usually react to darkness by increasing the proximity to their parents (Bowlby, 1973) but also adults seek more social closeness even to strangers in the dark (Baron, Rea, & Daniels, 1992; Gergen, Gergen, & Barton, 1973; Miwa & Hanyu, 2006). In sum, we assume that darkness amplifies people's inclination to approach each other.

In the present studies, we examined the effects of darkness on feeling close to and on approaching other individuals by focusing on cooperation. Cooperating with other people is a common way to reduce social distance and is a sign of social closeness (Clark & Mills, 1979). Hence, we hypothesized that individuals would be more likely to behave cooperatively if cooperation is functional to reduce social distance. In five experiments, we tested the main prediction as well as moderating and mediating variables.

Experiment 1A and 1B

Experiments 1A and B provided an initial test of the hypothesis that darkness would increase cooperation. In Experiment 1A. darkness (brightness) was manipulated by writing about a dark (bright) location (Steidle et al., 2011), whereas in Experiment 1B, indoor lighting was manipulated directly. Additionally, we also used different measures of cooperation. In Experiment 1A, participants then read conflict scenario about a joint seminar presentation (Baron et al., 1992) and indicated their likelihood to cooperate on an analogous scale. In Experiment 1B, cooperation was assessed with 5 trials of computerized social dilemma task ("the fishing game"; Sanna, Parks, & Chang, 2003). Here, cooperation was assessed as the sacrifice of own profit (number of fish people had returned) to save a common resource. As predicted, in Experiment 1A, participants in the dark condition were more willing to cooperate (M = 71.84; SD = 17.14) than participants in the bright condition (M = 62.50; SD = 19.79), t(78) = 2.25, p = .028, d = .50.In Experiment 1B, participants in the dim room (150 lux) made more cooperative decisions (returned more fish to the lake; M = 40.21; SD = 11.44) than participants in the brightly lit room (1500 lux; M = 32.66; SD = 10.57), t(56) = 2.61, p = .012, d = .69. Task difficulty, task motivation, fun, and mood were controlled in all experiments, but did not change the results. These results support that darkness (primed assumption our or physically manipulated) facilitates cooperation.

Experiment 2

We assumed that this effect would be mediated by an enhanced inclination for social closeness in the dark. To test this assumption, participants played а computerized version of the prisoner's dilemma (adapted from Axelrod, 1980) sitting in a dimly or a brightly lit room (150 lux vs. 1500 lux). This cooperation measure and lighting conditions were used in all subsequent experiments. To assess perceived social closeness to the partner, participants were asked how close they felt to their fellow player using the Inclusion Other in the Self (IOS) Scale (Aaron, Aaron, & Smollan, 1992). The sum of cooperative decisions served as a measure of the participant's cooperation. Perceived anonymity which is argued to be an important mediator of social behavior in the dark was also assessed (Thong et al, 2010). Replicating the results of Experiment 1A and 1B, participants in the dim room chose the cooperative win-win strategy more often (M = 2.96; SD = 1.43) than participants in the brightly lit room (M =2.09; SD = 1.38), t(46) = 2.15, p = .037, d =.62. Furthermore, participants in the dim room felt closer to their fellow player (M =2.80; SD = 1.21) than participants in the brightly lit room (M = 2.04; SD = .82), t(46)= 2.64, p = .011, d = .74. To test whether social closeness mediated the effect of lighting on cooperation, we used bootstrapping. Additionally, we controlled for perceived anonymity in our analysis. Results showed that the effect of darkness on cooperation was mediated by social closeness (indirect effect = .16, SE = .10, 95% confidence interval: .03, .38), but not by perceived anonymity (indirect effect = -.01, SE = .03, 95% confidence interval: -.17, .03). With the mediators in the model, the direct effect of darkness on cooperation was no longer significant. These results provide strong evidence that social closeness can explain the effect of darkness on cooperation.

Experiment 3

Experiments 3 and 4 aimed at testing dispositional and situational moderators of a darkness-related increase in cooperation. In Experiments 1A to 2, participants were confronted with a situation in which the fictive interaction partner always cooperated. In this case, cooperation helped the subjects to create social closeness. However. people's cooperation depends on their interaction partner (Twenge, Baumeister, DeWall, Ciarocco, & Bartels, 2007). If the interaction partner behaves uncooperatively, cooperation will not be functional. Trying to get close to such a person should not satisfy people's need for affiliation. To test this, we manipulated the fictive interaction partners' strategy in the PDG to be either cooperative and or uncooperative. Results showed no main effects of lighting condition and strategy condition, Fs(1, 43) < .01, p > .94, but as predicted, a significant interaction effect, F(1, 43) = 7.75, p = .008, $\eta^2 = .15$ (see Figure 2). Simple contrasts revealed that, only in the cooperative condition. participants behaved more cooperatively in the dim (M= 2.31, SD= 1.25) than in the bright room (M= 1.00, SD= .85), t(23) = 3.02, p = .006, d = .87. In the uncooperative condition, darkness had no effect on cooperation, t(20) = 1.13, p = .27. These support our hypothesis findings that cooperative behavior occurs under conditions that allow to reduce social distance.

Experiment 4

What happens when the situational conditions lose their signaling function because some people generally strive to reduce social distance? For instance, those with a chronically strong desire for social closeness tend to place less value on maximizing their own benefits and behave more cooperatively across many situations (Baumeister & Leary, 1995). In contrast, those with a low desire for social closeness tend to behave more egoistically. Therefore, particularly those who have no chronically strong desire for social closeness should be sensitive to environmental indicators of social distance, like darkness. To test this we measured participant's assumption, egoistic motivation, using the individualistic scale of the social value orientation (SVO; Van Lange & Liebrand, 1991). After this measurement, we used the same lighting conditions and cooperation game as in Experiment 2. As expected, the effect of darkness on cooperation was moderated by individualistic orientation, $\beta = .29$, t(58) =Simple slopes analyses 2.50, p = .015.showed that darkness promoted cooperation for participants high in individualistic orientation, $\beta = .62$, t(58) = 3.69, p < .001. In contrast, no lighting effect was found for individuals low in individualistic orientation, $\beta = .01, t(58) < .03, p = .98$. These results indicate that the darkness-related increase in cooperation is moderated by a dispositional desire for social closeness. Only those who are high in individualistic orientation showed sensitivity to darkness.

Discussion

The present paper investigated the effect of darkness on cooperation from a social distance perspective (Liberman et al., 2007). Across five experiments, being in the dark increased cooperation regardless of whether people imagined or really experienced the different lighting conditions (Experiments 1A to 4). This darkness-related increase in cooperation was mediated by feeling closer to the fictive partner (Experiment 2). This is in line with previous findings showing that darkness promotes a global information processing style (Steidle et al., 2011) because this processing style helps recognizing similarities between people and reduces social distance (Förster, 2009). Darkness appears to work as an environmental signal of social distance leading to compensatory affiliative behavior in the form of stronger cooperation.

The most important implication of our findings is that the positive effect of darkness on cooperation depends on the functionality of cooperation as a strategy to reduce social distance and achieve affiliation. This argument is supported by the moderation effects obtained in Experiments 3 and 4. Here, participants showed more cooperation in the dark when there were opportunities to reduce unwelcome social distance. In contrast, other researchshow that dim lighting conditions can also increase selfish behavior (Zhong et al., 2010) and negative stereotype (Schaller, Park, & Mueller, 2003). In this experiment, there was no possibility for participants to approach another person. Similarly, in our Experiment 3, darkness did not increase participants' cooperation when the partner was uncooperative. Hence, our results can be understood as an extension of previous findings. It is important for future research to identify the multiple ways in which situational variables, like darkness, can influence interpersonal processes.

To our knowledge, the present studies are the first to provide a consistent explanation of the effects of darkness on prosocial behavior in general and cooperation in particular. Our findings support the idea of grounded cognition and embodiment 2008) and the notion that (Barsalou, environmental conditions, such as darkness or lighting, can influence interpersonal perception and behavior. Moreover, the present findings contribute to the cooperation literature by showing that, not only the social situation, but also the environmental conditions can affect the behavior of the interaction partners (Salewski, 1993). In conclusion, this research offers a starting point to investigate the possibly wide-ranged impact of a basic environmental condition, namely illumination, on social cognition and behavior.

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Poster

Abstract Thoughts or Concrete Experiences: Darkness Triggers Cognitive and Affective Preferences

A. Steidle¹, A. Gibson², & L. Werth²

¹ University of Stuttgart, Stuttgart, Germany ² Chemnitz University of Technology, Chemnitz, Germany

Light and darkness produce mixed cognitive and emotional outcomes but it is rather unclear whether and how it changes our ways of thinking and feeling. The present paper addresses this question from a construal-level perspective (CLT; Trope & Liberman, 2010) because it has recently been demonstrated that darkness triggers a more abstract information processing style and is associated with high-level construals (Steidle et al., 2011). Cognitive and affective preferences or general tendencies can also differ in their construal levels. Based on CLT (Trope & Liberman, 2010), low-construal preferences involve a focus on details and concrete experiences within a given context, whereas high-level preferences involve abstraction, transforming the known and transcending the here and now. Hence, due to the association between darkness and construal level, we argue that darkness should lead to affective and cognitive preferences associated with а higher construal level than brightness.

Studies 1A and B tested our hypothesis on an implicit, associative level using a very general distinction between high-level and low-level preferences: thinking and feeling. Hence, darkness should lead to a preference of thinking and brightness to a preference for feeling. This assumption was confirmed by an Implicit Association Test showing that darkness is implicitly associated with thinking rather than with feeling and by a priming study. In this priming study, participants primed with brightness identified words related to feeling faster than participants primed with darkness. On an implicit level, the two studies support our assumption that darkness triggers cognitive

and affective preferences of a higher construal level than brightness.

Experiments 2A and 2B aimed at replicating the previous findings on a perceptual level using room lighting as a manipulation of darkness and investigating specific preferences associated with different construal levels: need for cognition (high level cognitive) vs. the need for closure (low level cognitive); sensation seeking (high level affective) vs. the need for affect (low level); preference for deliberation (high level decision making) vs. preference for intuition (low level decision making). As explained above, we expected that darkness should lead to affective and cognitive preferences of a higher construal level than brightness. This assumption was confirmed by a correlational study using a subjective measure of darkness and by an experiment manipulating darkness (1500 vs. 150 lx).

Across four studies, darkness was related to high-level preferences and brightness was related to low-level preferences. This is in line with previous findings showing that darkness promotes an abstract information processing style (Baron et al., 1992; Steidle et al., 2011) and with CLT (Trope & Liberman, 2010). Darkness appears to work as an environmental signal of abstraction and distance which influences our way of thinking and feeling. This adds to the notion of procedural embodiment stating that perception and body experiences influence the processing rather than the content level (Förster & Denzler, 2012). In sum, this research offers a starting point to investigate the possibly wide-ranged impact of basic environmental conditions on the way we feel, think and decide.

In the Spotlight: Brightness Increases Self-Awareness and Reflective Self-Regulation

A. Steidle¹, E. Hanke², & L.Werth²

¹ University of Stuttgart, Stuttgart, Germany ² Chemnitz University of Technology, Chemnitz, Germany

Introduction

Being in the spotlight means that an individual's behavior can be judged and evaluated by others. These situations evoke a state of heightened self-awareness in which individuals direct their attention to their own behavior, inner states, and standards and are motivated to bring their actual behavior in line with personal standards (Duval & Wicklund, 1972). Environmental cues triggering self-awareness automatically induce a perception of being observed such as eyes, cameras or mirrors (e.g., Bourrat, 2010). Darkness allows individuals to go undetected, while light makes individuals' behavior visible and observable for others. Hence, individuals should be motivated to make a good impression and to act in line with their personal and social standards. The present paper tested the assumption that, in contrast to darkness, bright light increases self-awareness and reflective self-regulation.

First, darkness and dim lighting conditions impair visual perception and recognition of other individuals. This reduced observation of others and by others can increase feelings of anonymity (Hirsh, Galinsky, & Zhong, 2011; Zhong, Bohns, & Gino, 2010) and a state of deindividuation (Gergen, Gergen, & Barton, 1973; Johnson & Downing, 1979) which represents a state of reduced awareness of the own identity and the perception of reduced accountability. Kasof (Kasof, 2001, 2002) proposes that bright light should increase self-awareness. In support, a study by Gifford (1988) shows that bright light increases the use of selfreferential words and self-disclosure which can be interpreted as a sign of heightened self-awareness. On a metaphorical level, many expressions related to high social control, attention on self or other's behavior make reference to light and visual perception: "to have an eye on someone", "to bring to light" and "hidden in the dark". In sum, in contrast to darkness, bright light signals potential observation by others which should lead to a heightened state of selfawareness.

Second, high self-awareness reduces disinhibition and leads to more controlled ways of self-regulation (Carver & Scheier, 1998). We argue that light and brightness as cues for self-awareness lead to similar results. Several studies confirm that bright lighting condition reduces disinhibition (Gergen, et al., 1973; Page & Moss, 1976). Kasof (2001, 2002) showed that selfrestrained eaters who preferred eating at dim lighting conditions were more likely to show bulimic behavior and deviate from normal eating behavior than those who preferred eating at bright lighting conditions. Kasof (2002) argues that heightened self-awareness should mediate these effects. In sum, light and brightness as cues for self-awareness should increase controlled and reflective behavior regulation. In the present studies, we examined the effects of brightness and darkness on self-awareness and behavior regulation.

Study 1: Brightness Increases Self-Awareness

Previous research provides indirect evidence that bright light increases selfawareness (Gifford, 1988; Kasof, 2001, 2002; Zhong, et al., 2010). However, up to date, no study directly tested this effect. We expected that, in contrast to darkness, brightness would heighten self-awareness. High self-awareness can be measured as a subjective experience. 1A, In Study following participants answered the

questionnaires after sitting for one hour in either at 150 lux (dim lighting) or at 1500 lux (bright light) horizontal illuminance on the table: public and private state-self-awareness (Ruisinger, 2003) and perceived anonymity (Zhong, et al., 2010). Participants in the bright room reported a higher public selfawareness (M = 2.45; SD = 1.13) than participants in the dim room (M = 2.01; SD =1.09), t(105) = 2.07, p = .041, d = .40, but there were no differences in private selfawareness or perceived anonymity, ts(105) <1, ps >. 75. Bright light apparently enhances people's concern about their impression on other people around them which supports our assumption that brightness increases selfawareness.

Studies 2-3: Brightness Increases the Preference for Reflective Self-Regulation

Generally, enhanced self-awareness leads to more reflective self-regulation (Carver & Scheier, 1998). Several studies already confirmed that dim room lighting increases impulsive behavior (Gergen, et al., 1973; Zhong, et al., 2010). Hence, we investigated the processes of reflective and impulsive self-regulation on the subjective level. A controlled and reflective regulation is characterized by a high level of self-control. Self-control refers to altering one's responses to bring them in line with socially desirable thoughts, feelings, and behaviors and to overriding impulses (Baumeister, Gilbert, Fiske, & Lindzey, 1998; Carver & Scheier, 1981). We expected that, in contrast to darkness, brightness as trigger of selfawareness would strengthen reflective forms of behavior regulation and self-control.

In Study 2, ambient lighting was set either at 150 lux (dim lighting) or 1500 lux (bright lighting). After one hour exposed to the lighting condition, participants assessed their current preference for an autonomous and a controlled self-regulation strategy (O'Hara & Sternberg, 2001). As expected, in the bright lighting condition, participants preferred a controlled (M = 5.43; SD = .63) to an autonomous self-regulation strategy (M =4.88; SD = .82), t(32) = -2.95, p = .006, d =.75. In contrast, in the dim condition, participants preferred an autonomous (M = 5.28; SD = .85) to a controlled self-regulation strategy, (M = 4.81; SD = .90), t(33) = 2.32, p = .027, d = .55. This pattern of results is in line with our assumption that brightness activates a more controlled and reflective style of self-regulation.

In Study 3, brightness (darkness) was manipulated using a word search task with words related to darkness (brightness). Participants then invented a story about two persons depicted on a picture and assessed their two characters regarding a reflective or impulsive self-regulation (impulsivereflective; spontaneous-planned; emotionalrational). Participants primed with brightness assessed the behavior of the characters in their study as more reflective and less impulsive (M = 3.09; SD = .65) than participants primed with brightness, (M =2.62; SD = 0.70), t(62) = 2.77, p = .007, d =.70. This shows that priming brightness facilitates the attribution of a reflective selfregulation which is in line with our assumption that brightness fosters this kind of self-regulation. In sum, the results of the two studies suggest that, compared to darkness, bright light or brightness priming both increase the preference for reflective self-regulation at a subjective and conscious level.

Studies 4-5: Brightness Increases Reflective Self-Regulation at the Implicit Level

However, Fitzsimmons and Bargh (2004) point out the importance of automatic and non-conscious processes underlying effective self-regulation, for instance, automatic goal priming or automatic goal pursuit. Hence, we investigated reflective and impulsive selfcontrol at the implicit level. We expected that, in contrast to darkness, brightness would strengthen implicit self-control by increasing the availability of duties rather than personal wishes and by implicitly reducing impulses.

In Study 4, brightness (darkness) was manipulated by wearing clear glasses or sun glasses (Zhong, et al., 2010). Participants were asked to recall their current duties and wishes (adapted from Willis & Rodriguez Bailon, 2010). The prevalence of personal whishes over duties (pleasure orientation) was computed by deducting the number of duties from the number of personal wishes. A high score signals a less controlled selfregulation. Participants primed with brightness had lower pleasure orientation (M = .95; SD = 1.96) than participants primed with darkness (M = 2.50; SD = 2.26), t(37) =2.62, p = .013, d = .73. This is in line with our assumption that brightness increases selfcontrol and reflective self-regulation.

In Study 5, brightness (darkness) was manipulated by writing about a dark (bright) location. Participants were smokers who have a chronically increased impulse to smoke and non-smokers who have no smoking impulse. After the priming, participants completed an Approach-Avoidance-IAT to assess their implicit impulse to smoking-related cues (De Houwer, Custers, & De Clercq, 2006). A negative IAT-score is typical for nonsmokers and indicates an impulse to avoid smoke-related cues. Craving or a high smoking impulse is represented by a more positive IAT-score (Waters, et al., 2007). Smokers generally possess this impulse although they know that smoking is unhealthy and that it would be better to quit. Hence, a reduced smoking impulse among smokers would be a sign of a less impulse and more controlled self-regulation. We expected that in the dark condition the smoking impulse would be stronger for smokers than for nonsmokers, but that there would be no difference in the smoking impulse between smokers and nonsmokers in the bright condition. Overall, smoker had less negative IAT-score than nonsmokers, F(1,211) = 1.37, p = .03, $\eta_p^2 = .02$. As expected, this main effect was moderated by priming condition, F(1, 211) = 6.64, p = .01, $\eta_p^2 = .03$ (no main effect of priming, F(1, 211) = .60, p= .44). In the dark condition, smokers had a less negative IAT-score (M = -.17; SD = .51) than nonsmokers (M = -.57; SD = .51), t(116)= 3.47, p = .001, d = .78, which signals that nonsmokers automatically avoid smokerelated cues more than smokers. This difference disappears in the bright condition: smokers did not show a weaker avoidance score (M = -.46; SD = .68) than nonsmokers (M = -.42; SD = .53), t(95) = -.29, p = .77. Hence, priming brightness apparently fosters the generally weak impulse of smokers to avoid smoking-related stimuli. Moreover, after brightness priming the automatic avoidance reaction of smokers is comparable to the reaction of nonsmokers. This supports our assumption that brightness leads to a more reflective self-regulation.

The presents finding show that, compared to darkness, brightness reduces the prevalence of personal wishes over duties and weakens the automatic smoking impulse in smokers. In sum, this supports our assumption that brightness increases reflective self-regulation and self-control on the implicit level.

Discussion

The present paper investigated the effect of brightness and darkness on self-awareness, reflective behavior regulation, and selfcontrol. In Study 1, brightness increased the focus on and availability of the self in form of heightened public self-awareness. It is well-known that self-awareness increases self-control and a reflective form of behavior regulation (Carver & Scheier, 1998; Carver & Scheier, 1981). Hence, we assumed that brightness as a cue for self-awareness would also promote controlled behavior. Four studies supported this assumption on explicit (2 and 3) and implicit measures (4 and 5). This adds to previous research regarding the inhibiting effects of bright light on behavior (Gergen, et al., 1973; Page & Moss, 1976; Zhong, et al., 2010). Taken together, darkness change selfbrightness and awareness and controlled behavior at implicit and explicit levels regardless of whether darkness and brightness were perceptually manipulated or primed.

Previous research argued that anonymity and reduced accountability caused the disinhibited behavior in the dark (Page & Moss, 1976; Zhong, et al., 2010). Recently, Hirsh and his colleagues argued (Hirsh, et al., 2011) that darkness should decrease the activity of the Behavior Inhibition System (BIS) which in turn should reduces disinhibition. The present findings confirm this assumption by showing that, in contrast to darkness, brightness increased the salience of desirability concerns (heightened public self-awareness) and focus on reflective and less impulsive self-regulation. Moreover, the framework suggested by Hirsh (Hirsh, et al., 2011) assumes that brightness and darkness would affect the reflective BIS but not the more impulsive Behavior Activation System (BAS). Our studies 2-4 suggest that brightness not only strengthens inhibitory forces but can also change variables which are rather part of the BAS than the BIS, for instance, smoking impulse. Hence, it would be interesting for future research to explore the multiple implicit and explicit ways by which brightness and darkness influence our view on our self and our self-regulation.

An important implication of the current research is that brightness and darkness both as perceptual experience and as conceptual priming - affect self-regulation at implicit and explicit levels. These results posit the questions of how brightness and darkness are represented in memory, how it unfolds its influence on an implicit level, and how it contributes to the grounding of behavior regulation. Further research embedded in grounded cognition approaches (Barsalou, 2008) are needed to answer the questions.

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Attention Equivalent: A Study on the Effectiveness of Individual Lighting Parameters on the Perception and Preference of Customers in a Shop

B. Tralau¹, C. Fröhlich¹, J. Ejhed², R. Greule³, & M. Felsch⁴

¹ Zumtobel Lighting GmbH, Dornbirn, Austria ² KTH Royal Institute of Technology, Stockholm, Sweden ³ HAW Hochschule für angewandte Wissenschaften, Hamburg, Deutschland ⁴ Felsch Lighting Design, Hamburg, Deutschland

Problem

For many years we assumed that an increase in the brightness of a shop window or a shop goes along with an increase in the attention of passers-by. A direct relationship between light intensity and attractiveness could be detected. /1/,/2/ But this requirement is nowadays highly inconsistent with the energy efficiency requirements. New ways must be found now that also mean an impact on the attention of potential customers.

The aim of the presented study is to find an attention equivalent to the brightness in the retail lighting and to analyse which factors in retail lighting are critical that customers stay there longer, more customers come into the shop and finally decide it for a purchase of goods.

State of science

Many studies concerning perception psychology justify the arrangement of goods and analyse general viewing behaviour during a purchase process. /2/,/3/,/4/,/5/

Another aspect which can be found in the literature is the emotional effect of the retail environment, where also light plays an important role./6/ Quartier saith that often it is a unique environment which becomes necessary for customer binding and lighting has an emotional and psychological effect through the perceptual system. /7/

Only a very few studies show the effect of individual lighting parameters on the purchase behaviour and length of stay of customers. One study from Freyssinier should be mentioned./8/ He analysed the potential for energy savings in retail display windows by using coloured light in the background and reducing the power used for accent light. The result of that study allow the consequence that there is a possibility next to increasing only the illuminance level to find an equivalent of attention using other lighting parameters, such as a coloured background lighting.

The study explained below leads to new findings in the area of retail application research.

Research hypotheses

The study is intended to demonstrate that not only the brightness of a shop window or a shop is decisive for its level of attraction. Less is sometimes more. As such, precisely implemented accent lighting can create focal perception points and attract the attention of observers. In addition to attractiveness, however, two further important factors for turnover and customers' length of stay in a shop are well-being and simple orientation. Both can be achieved by horizontal lighting in addition to vertical accent lighting.

- What influence does the lighting have to achieve this effect?
- Which factors and combinations of factors create the effect?
- Is there a difference between preference and attention with the various factors?
- Are there different preferences for different target groups (type of customers / lifestyle)?
- Is the preference / attention different for different objects / materials / interior design?

• Is there a difference for preferences with different perspectives or zones in a shop (distances)?

Research methods

Due to the very broad field of investigation questions the research follows an explorative approach. Target of this explorative approach is to find out first aspects, which show an effect and which are worth to investigate more in detail.

Therefore the research project was split into several sub-sections and various methods were applied.

First an online questionnaire was drawn up to initially gain the preferences or subjective judgement of customers (see Fig.1). The benefit of this questionnaire was that a large number of test subjects could be reached internationally and flexibly. The results could be simply exported. The online questionnaire is based on the subjective comparison of various lighting solutions, and these solutions could be interactively optimised or evaluated. Visualisations were used for evaluating the various light situations. The visualizations are done for the three main decision zones within a retail space. First, for the retail display window, were the customer decides to enter a shop or not. Secondly, the spatial perspective, which you have just after entering a shop and where the orientation plays the most important role. Thirdly the shelf perspective, where the actual purchasing decision is made.

Simple lighting parameters such as brightness, colour temperature and light distribution were varied or visualised within the lighting solutions. With that variety first ideas of which type of light is preferred and gets the highest attention could be analysed. The following types of questions or scales were used:

- Selection question (e.g. "Which of the three lighting solutions do you like the most?")
- Rating scale (e.g. "How satisfied are you with the lighting solution?")
- Setting (e.g. by selecting optimum light distribution via manual adaptation)



Fig. 1: Questionnaire to compase different lighting scenarios

In order to eliminate as many influence parameters as possible, the analyses were carried out using relatively abstract objects. This means the brand effect is disregarded to the greatest possible extent. The objects, the materials and the saturation of colours were varied as well, to find out the relation between lighting parameters and object properties. Shiny, transparent or matt surfaces allow evaluation with a focus on the lighting effect.

97 people from all over the world took part in the survey. Around half of the test subjects were female, the other half of the participants were male.

After the online survey, perception via an eye-tracking process was evaluated. Here the project was once again split into two sub-sections: laboratory analysis and field trial./9/

The lighting factors that were to be investigated included light colour, light distribution, lighting intensity and dynamic changes in brightness or colour. Laboratory tests using test charts produced generally valid statements regarding visual effects such as contrast and colour perception. Test charts were created that reflected the fundamental principles of perception. The test charts were created as graphics and flash animations and embedded in an overall PowerPoint presentation. The test stimuli were always shown on a black background. Only the "first glance" of the specific test subject was considered for all test charts with static contents. For evaluation of this first glance, the coordinates on the slide were determined the test subject first looked where immediately after a new slide appeared.



Fig. 2: Eye-tracking (Douglas store)

With the dynamic modifications, it was determined which change was recognised first and how much time this recognition took from the beginning of the slide.

In the second phase, measurements in realised projects were implemented in order to transfer the findings gained from the laboratory study into practice.

The measurements carried out in the Douglas and SPAR shops primarily referred to a localisation of the "points of attraction" (see Fig. 2).

The test subjects were given a short introduction of the intended test and were informed about how to behave during the test. Then the eye-tracking system was set up for the specific person. The test was started after calibration of the system. The test subjects were given the task of choosing a pair of glasses for themselves, if possible with frame arms of wood. The task was intended to increase the subjects' attention while viewing. The test subjects were not given any other instructions, and the duration was also not limited.

Evaluation was carried out graphically. The "gaze positions" of the test subjects were transferred point-for-point into a graph of the room observed. The single points in the sequence of their observation were connected with lines so that the sequence of the observation could be recognised in the evaluation.

Results

Previous findings claiming that maximum possible brightness in a shop increases attractiveness could be refuted.

Instead, the study demonstrated that the most difficult visual task, i.e. the largest contrast concerning the visual task, influences its detection and attention. Perception of



Fig. 3: Heatmap of Shop window evaluation /10/

contrast depends here on the ambient brightness. The brighter the surroundings, the more marked the contrast must be. Even small differences in luminance levels are effective in dark environments.

It was also shown that vertical illuminance levels support orientation in the space and that simple orientation supports the decision to enter a shop. Here considerable differences in the evaluation of men and women became apparent. While men view a retail space more extensively in its entirety, women look at a retail space more intensely and in greater detail (see Fig 3).

Supplementary horizontal illuminance increases the preference and well-being of the user. The light distribution depends on the lighting's character. Goods have a more attractive and exclusive effect when light is focused on them more precisely and in more detail. Stimulation via accent lighting, but also by backlighting the lower third of a shelf, leads to higher perception of this area, resulting in an extension of the amount of time customers stay there and in higher turnover.

The results specified here are only excerpts from the complete documentation.

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Stakeholder Perception of the Intangible Value of a Public Lighting Solution in an Ecological Zone

E. den Ouden¹, J. Keijzers², A. Szóstek³, & E. de Vries⁴

¹ Industrial Design, Eindhoven University of Technology, Intelligent Lighting Institute, Eindhoven, The Netherlands

² Fontys University of Applied Sciences, Eindhoven, The Netherlands ³Interdisciplinary Center for Applied Cognitive Studies, School of Social Sciences and Humanities, Warsaw, Poland ⁴ THE LUX LAB Lighting Design, Eindhoven, The Netherlands

Introduction

New lighting technologies are going to create a revolution in the lighting industry. According to Aarts (2011), the lighting industry will go through an evolution similar to the developments in computing since the invention of the first transistor. In the next 12 years, 80 billion light bulbs will be replaced by leds. Led technology offers many advantages, such as chromaticity control, better light quality and higher efficiency (Shur & Zukauskas, 2005).

One of the application areas for new lighting solutions is public lighting. With the extended possibilities that led offers, and integration with smart sensor networks, new opportunities arise to further reduce energy use and light pollution, and, at the same time, increase people's sense of perceived personal safety and comfort. Municipalities aim to implement such solutions, but little is known yet about their acceptance by the general public, nor the effects on the perceived safety and comfort.

The municipality of Veldhoven, The Netherlands asked THE LUX LAB to design a smart lighting solution for a bicycle path that runs through an ecological zone. The proposed solution aimed to use different lighting settings (varying in color and intensity) at different times to accommodate different stakeholders (see: Figure 1) The proposed solution offers the following settings:

In the early evening the path is intensely used by commuters, particularly children heading home. This is why lighting was placed in that zone in the first place. Cyclists' feelings of comfort and safety are increased with more light, as people need more light when dusk is setting. Thus white, 5 lux light is proposed for this time of day (setting A).

Later in the evening as traffic ceases the light dims to a light that is less disturbing for animals and plants but still provides good visibility for cyclists (setting B: yellowgreenish, 3,5 lux). The yellow-greenish light offers good visibility at significant lower energy use caused by led efficiency in such color range combined with high sensitivity of people's eyes to these wavelengths.

During the night as there is hardly any traffic the wild life becomes the most important stakeholder. Therefore, the light is



Fig. 1: Design sketches for the lighting scenarios (THE LUX LAB, 2010)

dimmed to the equivalent of 'full moonlight' (setting C: cool white, less than 1 lux), which does not disturb animals and at the same time requires significantly less energy while stays aesthetically pleasing. In the case of an emergency the system automatically gears up to increased lighting levels to ensure maximum safety for the incidental cyclists.

In the morning bright cool white lighting setting (setting D: cool white, 7 lux) is used to increase alertness of the cyclists.

The proposed solution differs from traditional lighting installations as it aims not just to reduce the energy use but at the same time to increase life quality in the ecological zone while not sacrificing safety of the road users. The role of the designer is to understand the needs and requirements from the various stakeholders, and to integrate seemingly opposing needs into a solution that is attractive, or at least acceptable, to them. The difficulty in these kinds of projects is that the solution is very different from what is currently available, so for the stakeholders to be able to judge the concept they will have to be able to imagine it. Moreover, to address issues like perceived safety and comfort means that potential users should be able to assess the intangible values of the concept.

Testing traditional lighting for public spaces involves comparison of different lamp types or lighting settings for a similar purpose (Boyce & Bruno, 1999). In this case, as the different light settings were part of the same concept we knew that some conditions, like night setting, would be perceived as less safe due to its low luminance (Boyce et al, 2000). So, the question was not which of these settings would be preferred but whether using different settings over the course of the night is acceptable for different stakeholders. Furthermore, we wanted to know if such people knowing that such lighting aims to accommodate flora and fauna in the ecological zone would influence their acceptance. The research program 'Brilliant Streets' of the Intelligent Lighting Institute at TU/e was invited to support the concept evaluation in line with the reflective transformative design process (Hummels & Frens, 2008).

Study design

For the first iteration in the reflective transformative design process, а demonstrator was created which was then shown during the 'Liberation of Light' exhibition. For setting A a less bright setting with a high color rendering was chosen, to avoid a longer accommodation times to the less bright settings in B and C. In the demonstrator the settings A (1,32 lx Ra 90.2 K 2507), B (3.44 lx Ra 61.8 K 4283), and C (0,21 lx Ra 81,9 K 3966) were presented in darkened corridors. This allowed people to experience the lighting levels and assess the concept. Due to restrictions in available space setting D was left out..

The demonstrator was used to collect feedback from relevant stakeholders using methods. First. an interactive two questionnaire was used to measure light setting preference and perceived level of safety for the general public. Visitors of the exhibition were asked to complete a short questionnaire after exiting the experiment area. After answering a set of questions regarding the preference for each separate light setting, participants were asked to rate the light settings with relation to their feelings of safety by using VERO tool (Szostek & Karapanos, 2011). In short, participants were asked to drag each light setting onto a circle. The closer a given lighting design was placed to the center of the circle the higher was the level of perceived safety. Additional measurements for age, gender and frequency of bicycle usage were used.

Secondly, workshops with different stakeholders were conducted. The goal of these workshops was to collect feedback from multiple points of view and to facilitate an elaborate discussion on the validity of the lighting solutions in the surroundings of an ecological zone. These stakeholders included the municipality, people living in the neighborhood, local police, an environmental organization and also other users: school children, athletes who use the path for their weekly running exercise and elderly. A workshop consisted of the following steps:

- 1. Visit to the demonstrator
- 2. Reflection on the concept
- 3. Concept presentation using video material
- 4. Reflection on the concept
- 5. Evaluation of the importance of the key parameters of the concept for further development

'Stakeholder types' were not mixed in the workshops and at least two individuals participated representing each 'stakeholder type'. An independent facilitator was invited to facilitate the discussion on the value of the concept.

Results

Firstly, the results of the questionnaire are discussed and then the qualitative insights regarding most important outcomes from the workshops are presented.

A total of 966 persons volunteered to fill in the questionnaire. However, due to incompleteness of records, 602 answers were used for the analysis. Among the participants 283 were male (47%) and 391 female (53%). The majority (60%) rode a bicycle daily. Among those, 13.5% of people rode a bicycle daily after dark.

The majority of participants either preferred setting A (46.3%) or had no preference regarding the light for bicycle paths (36.3%). Setting B has been chosen as the preferred one by 14% and setting C by 3.3% of people. There was no difference with respect to the light preferences by people of different age (X2=.062, d.f.=21), gender (X2=.101, d.f.=3) and frequency of riding a bike after dark (X2=.735, d.f.=12). Significant difference was detected that depended on the overall frequency of riding a bike (X2=.044, p<0.05, d.f.=12). The study showed that participants who either never or about once a year rode a bicycle had no preference for one of the light settings. If they showed preference they would most often select B and then A as preferred settings. Participants riding bicycles more frequently (once a month, once a week and daily) showed strong preference for A, then none and then B.

Similarly, the results of the repertory grid technique showed that setting A was perceived as the safest (mean distance from the center = 85.41, median = 71.72, dominant = 50), then B (mean = 95.25, median = 94.59, dominant = 50) and finally C (mean = 141.51, median = 141.51, dominant = 150).

Furthermore, the analysis showed that gender, the overall frequency of cycling or frequency of cycling after dark) did not differentiate the perception of the tested light conditions as more or less safe. With respect to age, significant correlation (.002, P < .001) was detected in the case of setting B, which was perceived as the least safe among the youngest and the oldest participants. The group who considered setting B as relatively safe was between 41 and 70 years old.

A and B settings were considered as the most similar in terms of safety (mean = 62.96; median = 61.2), while B and C were seen as the least similar (mean = 105.68, median = 108.94). Based on the t-test for two dependent samples with normal distributions can be concluded that the perceived similarity between A and B is significantly different from the perception of similarity between B and C (t = 19.96, p < .000).

The results gathered during the 7 workshop sessions are summarized in Table 1. The first important observation is that although all stakeholders were at least fairly positive towards the concept as a whole, the ranking of key parameters for its further differed development significantly. Interestingly, the road users indicated energy efficiency to be the most important parameter, whereas municipality marked it as the least important one. This seems to indicate that citizens expect from municipalities to find a balance between energy efficiency on the one hand and social safety and ecology on the other. Furthermore, during the workshops multiple questions arose that mostly related to the perception of safety. Example are: can we control light intensity in the case of emergencies; would green and yellow lighting result in unwanted changes in color perception; does car and urban lighting in the surroundings change the atmosphere?

	Police	Supplier	Environmental organisation	Users	Municipality
Ecology	4	3	1	3	2
Social safety	1	2	2	2	1
Energy efficiency	6	4	3	1	6
Atmosphere	2	1	4	4	3
Promotional value	5	6	5	5	5
Purchase and maintenance costs	3	5	6	6	4

Table 1: Overview of the ranking of key parameters

Conclusions and discussion

This research aimed to generate insights regarding the perception of intangible value of light settings as experienced by different stakeholders. One of the most prominent difficulties in testing such radical innovations is to ensure that the participants understand the concept properly. For the concept presented in this article, two problems arose during concept evaluation: 1) despite using a demonstrator the lighting concept and its associated values were still intangible; 2) the concept itself is dynamic for which people have no previous reference.

In line with the previous research, the quantitative results confirmed that settings with higher light levels were preferred. But the results also suggest that a lower light level with a high color rendering is perceived as similar to a higher level with lower color rendering. This is an aspect for further study.

Although the experimental set-up was not similar to a realistic outdoor situation, the fact that people could experience the light settings give rise to interesting discussions on the different stakeholder perspectives. This confirmed the usefulness of this co-reflection session in an early phase of the project to elicit stakeholders' needs. Moreover, the results of the co-reflection proved to be a strong element in building commitment from a supplier to invest in the production of specific prototypes for a next iteration.

This study had some limitations. For people participating in the survey it may not have been clear enough that the three settings were to be used over the course of the night, so they might not be triggered to reflect on the settings in relation to the probability of them using the path at the respective time blocks. Further research aims to address these limitations and will include new moments of reflection when a limited set of prototypes is placed on the real-life situations (2012) and longitudinal studies when the complete installation is placed (2013). It will also further study the perception of different combinations of light and color rendering levels.

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Preference for Key Parameter of Tone Mapping Operator in Different Viewing Conditions.

M. G. M. Stokkermans, M. J. Murdoch, & U. Engelke

Philips Research, Eindhoven, the Netherlands

Introduction

The outside world offers, and the human visual system is capable of dealing with, a much larger luminance range than can be displayed on a regular display. Highdynamic-range (HDR) photographs or renderings therefore have to be compressed in dynamic range to be displayed. To preserve the visual appearance of the original scene, tone mapping operators (TMOs) are used (Reinhard, Ward, Pattanak & Debevec, 2006).

The key of a scene is a subjective concept derived from photography that indicates how light or dark the scene is perceived. High-key scenes are for instance white-painted rooms, and low-key scenes are for instance dark parking garages (Reinhard, Stark, Shirley & Ferwerda, 2002).

For an image of a scene to be perceived similarly to the scene itself, the scene key must be preserved in the image reproduction. This may be done in the exposure settings or via a specific parameter in a TMO. For the current study we focus on Reinhard's photographic tone reproduction operator for digital images (Reinhard et al., 2002), which provides a key parameter that affects the overall intensity of the reproduction. The key parameter may be individually set to a preferred value, or computed via algorithm depending on the minimum, the maximum, and the average luminance values of the scene (Reinhard, 2003). For scenes where the average luminance is closer to the maximum luminance than to the minimum, a high key is preferred.

However, for determining the preferred key of an image reproduction, more than only the luminance values of the scene itself are important. Key preference can also depend on viewing conditions. Mantiuk, Daly and Kerofsky (2008) include possibilities for different display and ambient settings in their TMO, and Reinhard (2003) also confirmed that certain images could still benefit from manual parameter selection due to viewing conditions.

How viewing conditions can affect key preference can be best anticipated by considering a few color-appearance phenomena. Firstly, simultaneous contrast describes the effect that the same stimulus appears lighter on a dark background, and vice-versa (Fairchild, 1998). Secondly, the Hunt effect (Hunt, 1952) and the Stevens effect (Stevens & Stevens, 1963) respectively describe that colorfulness, and brightness (or lightness) contrast increase with increasing Therefore objects typically luminance. appear more vivid and have more contrast outside in the sun, than indoors (Fairchild, 1998). Lastly, Bartleson and Breneman (1967) found that perceived contrast of the image increased with increased surround luminance (Fairchild, 1998).

For the present study we hypothesize that the TMO key parameter can be used to compensate for different viewing conditions, to optimize image appearance.

Methodology

Design

This study followed a within-subject design using two display luminance settings (full white: $102 \text{ vs.} 550 \text{ cd/m}^2$), two surround (wall washing behind display) luminance settings ($20 \text{ vs.} 275 \text{ cd/m}^2$), and three different images (1: HDR rendering of an office room; 2: HDR photograph of a lab booth; and 3: HDR photograph of snow scene (see Figure 1)). The dependent measure was the preferred key value, and was assessed twice for every condition, to determine within-observer consistency.



Fig. 1: 1) Rendering of office room, 2) Photograph of lab booth, 3) Photograph of snow scene.

Stimuli

The images were specifically chosen to research both high-key and low-key scenes. The image of the room was a physicallybased rendering of an accurate 3D model, and the two HDR images came from Fairchild's HDR Photographic Survey¹. The key parameter of the images was adjusted and tonemapped using the freeware Luminance HDR² with TMO 'Photographic reproduction for digital images' tone (Reinhard et al., 2002). For the room rendering, participants could choose from 47 different key values, ranging from 0.005 to 1. For the snow scene, there were 45 different key values, ranging from 0.0025 to 1. For the lab booth photograph, there were 34 different key values ranging from 0.0025 to 0.25. The key parameter affects the image in a visually non-linear fashion, leading to a larger increase in perceived intensity at the lower part of the scale than in the higher parts. Thus, we selected levels of the key parameter distributed so that we could present them to the participants in an approximately visually linear way. Because the room and snow scene are originally high-key scenes, we selected a larger range of key values for the participants to choose from than for the lowkey lab booth scene.

All images were shown on a calibrated NEC P462 46" LCD. The participants sat at a distance of one meter from the display, and the image was presented with a width of 53° of their field of view. The surround was illuminated from a cove located at ceiling height (3.25 meter), 0.9 meter behind the display, directed at the wall.

All images were presented in four blocks of equal display/surround luminance (for convenience with respect to adaptation time). The four blocks were presented in a counterbalanced order, and within each block the images were randomized.

Participants

A total of 20 participants (10 male, 10 female) participated in this study. Their average age was 26.2 (Standard Deviation: 3.9), ranging from 22 to 38. The participants had various nationalities and backgrounds.

Procedure

We welcomed the participants and asked them to take a seat in front of the display. First, the participants read the instructions and informed consent form. Then, the participants adapted for three minutes to the surround lighting/display settings of the first block while looking at a mid grey image at the display. After adapting, the first image was shown. To avoid confusion about the term 'key', we asked the participants to select their preferred intensity for that given image and viewing conditions. This could be done by using the arrow keys of the keyboard. Next, the researcher recorded the result and showed the following image. After completing each block, the participants adapted for three minutes to the next surround/display settings, before the next block started.

Analyses

To test the hypothesis as stated in the introduction, correlation analyses, and a repeated-measures ANOVA were performed using SPSS 17.0. For statistical analysis, the key values were first transformed to a visually linear scale (the levels presented in the experiment). For visualization in tables and graphs, the original key values are shown.

Results

Results showed that there was a clear distinction in preferred key value between

¹ http://www.cis.rit.edu/fairchild/HDR.html

² http://qtpfsgui.sourceforge.net/



Fig.2: Key preference depending on display and surround luminance and on original scene key (low key scene is lab booth; high key scene is average of room and snow scene).

the low and high-key scenes [F (2, 18) = 480, p < .001]. The rendering and the snow scene were high-key, and were also preferred in a high key by the participants. Post-hoc results further showed that there was no significant difference between these images (p = .444). The lab booth was a lower key scene, and was also preferred in a lower key. The differences in key preference of the lab booth compared to both the rendering and the snow scene showed significant post-hoc test results (p < .001). This is also clearly visible in Figure 2.

Besides this, effects of display and surround luminance on key preference were both found. Higher display luminance values led to a lower preferred key value [F (1,19) = 71.2, p < .001], while higher surround luminance led to a higher preferred key value [F (1,19) = 21.6, p = .001]. There was no significant interaction effect of surround luminance and display luminance [F (1,19) = 1.25, p = .277]. Interaction effects were present for both surround luminance and the

Table 1: Mean (M) & Standard Error (SE) of key preference repeats per image, averaged over all conditions.

Image	Preference 1		Preference 2	
	Μ	SE	М	SE
1) Rendering	.350	.028	.372	.032
2) Lab booth	.071	.004	.077	.005
3) Snow scene	.339	.036	.36	.038

original key of the scene [F (2,18) = 15.2, p < .001], and for display luminance and the original key of the scene [F (2,18) = 25.3, p < .001], pointing towards larger effects of surround and display luminance for high-key scenes than low-key scenes. All these effects are also depicted graphically in Figure 2.

Considering within-observer the consistency regarding this preference, results showed a high Pearson correlation between and the second preference the first assessment of .823 (p < .001). On the other hand, the ANOVA showed that the two repeats of preference were significantly different from each other [F(1,19) = 7.9, p =.011]. Looking at the preferred key values themselves provided some perspective: the average difference is 1 'step' or less, so we argue that the consistency in preference is quite good. Table 1 provides information regarding the two preference measures for each image.

Discussion

A few interesting conclusions can be drawn from the present study. Firstly, people set the key parameter for the images similarly to how we would categorize the original scene as high or low-key. Secondly, as expected, this study showed that preference for key depends also on the viewing conditions (display and surround luminance) in which the image is assessed.

Results showed that increased surround luminance values led to an increase in preferred key. Intuitively it makes sense that for instance for comfort reasons, participants did not want a large difference in perceived brightness between the display and the surround, and compensated for this by increasing the key of the image. The simultaneous contrast phenomenon possibly even enhanced this effect. However, besides this, the Photographic TMO has а confounding effect: at higher key values, contrast is reduced in the light areas of the image (Reinhard, 2003). Thus, because increased surround luminance leads to increased contrast perception (Bartleson & Breneman, 1967), participants might have compensated for both this effect and the overall luminance at the same time by increasing the key.

We found that increased display luminance led to lower preferred key values. This is probably again to keep the total perceived brightness ratio of the image and display versus the surround similar. Additionally, it is also possible that people may have corrected for the Hunt effect. Regarding the Stevens effect (perceived contrast increases with luminance); we acknowledge that this is contradicting earlier reasoning. However, we think that preferred key might have decreased even more if this were not coupled to a contrast increase.

Furthermore, this study stresses the importance of the display. Display luminance has a larger effect on key preference than surround luminance, even though the change in surround luminance was 2.5 times larger than the change in display luminance. This seems rational because the display of course dominates central vision.

The present study focused on two variables with two luminance values, which makes it difficult to generalize conclusions for a wider range. We selected these values since they cover typical values for normal viewing environments. However, researching intermediate values, or possibly even more extreme values in future studies, would provide valuable information. Nevertheless, we believe the present study is a first step to accounting for the effect of viewing conditions in tonemapped images.

Additionally, we think that other factors should be taken into account as well. For instance, for the surround luminance, it is important how the luminaires are directed. In our set up, cove luminaires were close to the wall behind the display, and caused minimal reflections on the display. In the study of Mantiuk and colleagues (2008), the ambient lighting was directed on the display and therefore did cause reflections. Their results showed that increased room lighting or outside lighting led to lower contrast, and adapted their TMO to compensate for this. Since this difference in set up might lead to different results, we argue that the possibility of reflections of the display is an important variable to take into account.

Lastly, comparing the displayed HDR image directly to a real environment would be interesting for future research, though we realize that doing so will require careful handling of adaptation.

Conclusion

This study showed first results regarding the effect of viewing conditions on preference for key as a TMO parameter. Increasing surround luminance led to higher preferred key values, while increasing display luminance led to lower preferred key values. Therefore, it is important to account for the effect of viewing conditions while tuning the key parameter in a TMO. However, before this can be generalized, or implemented in a TMO, it is advised to study a wider range of luminance values, and possibly also take other factors like reflection of the display into account.

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The Effect of Colored Light on Arousal and Valence in Participants Primed with Colored Emotional Pictures

R. J. E. Rajae-Joordens¹, & I. Hanique²

¹ Philips Research, Eindhoven, the Netherlands ² Radboud University Nijmegen, Nijmegen, the Netherlands

Introduction

In earlier days, Gerard (1958) and Wilson (1966) investigated the relation between colored light and several arousal-related physiological measures. Gerard reported a polarity between red and blue colored light illumination, with red being on the warm or high arousal pole and blue being on the cool or low arousal pole. In addition, Wilson found that red induced higher arousal levels than green. Both researchers claimed that different colored illuminations induce a differential physiological activation.

After the discovery of the intrinsically activating properties of blue light mediated via the retinal melanopsin (Yoto et al., 2007; Lockley et al., 2006), the arousing effect of red light should be questioned. Mikellides (1990) suggested that not hue but rather variations in saturation caused the arousing effect of red light reported by Wilson and Gerard. Support for this reasoning comes from Robinson (2004), who noticed that the green and red stimuli in Wilson's study indeed were not equated with regard to lightness and saturation.

Furthermore, not only an improper design, but also cognitive processes might explain the different hue effects on arousal in the different studies. Gerard reported that red light evoked a variety of unpleasant associations related to blood, injuries, fire and danger, while blue light was associated with positive thoughts such as friendliness, romantic love and blue skies. Similarly, Mehta and Zhu (2009) reported that red was associated with danger and mistakes, whereas blue was associated with peace and openness. These observations indicate that increased arousal not necessarily means that one feels positively energized, but can also reflect anger, fear or other unpleasant feelings. Therefore, to get an answer on the question whether short exposures to colored light affect arousal, a properly controlled study, measuring not only arousal, but also valence, i.e. the intrinsic attractiveness (positive valence) or aversiveness (negative valence), should be performed.

Based on these considerations, Rajae-Joordens (2011) designed an experiment in which the effect of hue (red, green and blue), lightness and saturation of 60-sec colored light exposure on arousal and valence was investigated. Red light was found to be less pleasant and more arousing than green and blue light as measured by subjective evaluations, and saturated light was assessed to be more arousing than desaturated light. Conversely, no clear physiological effects were found, and moreover, participants indicated to have no associations.

Because Gerard's participants reported unpleasant arousing associations in red light and positive calm thoughts in blue light, the question arose whether Rajae-Joordens would have found an effect on physiology if the light stimuli had triggered positivecalming or negative-arousing associations in her participants as was the case in the study of Gerard. To address this question, we repeated the Rajae-Joordens experiment investigating the effect of hue (red, green, and blue), lightness, and saturation of twelve 60sec colored light stimuli on arousal and valence. To enable color-induced associations, participants were primed with predominantly red, green, and blue colored pictures with a positive-calming or negative-arousing emotional content before being exposed to twelve colored light stimuli. Valence and arousal were examined by means of subjective evaluations and a variety of objective physiological measures.

Material and Method

Stimulus selection

Twelve emotional pictures (6 positively calming and 6 negatively arousing) with one predominant color (4 red, 4 green, and 4 blue) were selected (see Fig.1). To create a balanced design in which each participant was primed with four negative pictures of two colors and four positive pictures of two other colors, we also selected two positively calming and two negatively arousing white pictures. Consequently, each picture was presented to half of the participants.

Using CIELAB color space (4300K as reference white), we defined twelve light settings of three different hues, two different saturation levels, and two different light levels (see Table 1) for the five RGB LED wall washers (16 LEDs per color). Saturation was defined as $((a^2+b^2)0.5/L^*)$. Due to technical limitations, the lightness of the saturated and desaturated blue light stimuli was lower than those of red and green. As a consequence, three analyses were needed. In a first analysis of hue, saturation and lightness effects, only red and green light data were taken into account. In a second analysis testing the hue and saturation effect of red, green and blue light, only 63%-lightness data were used. Finally, a third analysis was performed on blue light data only to test the lightness and saturation effect of blue light.

The CIELAB reference white for the light stimulus selection, obtained by the fluorescent light units in the ceiling (4300K, 500 cd/m^2) while the wall washers were off, was also chosen as the neutral setting in-between two light stimulus presentations.

Experimental Procedure

Forty participants (18 females and 22 males, age 21-51 years) without any form of color blindness took part in this study. Electrodes were placed in order to capture skin conductance, respiration, blood volume pulse, and skin temperature by means of a NEXUS-10 (Mind Media BV, the Netherlands). Thereafter, a sub-selection of eight priming pictures was presented two times 10 sec on a LCD-TV located in the corner of the neutrally lighted test room.

Subsequently, the participant took place on a chair facing a white wall with the wall washers located on the floor in such a way that their light output fully covered this wall. After a 3-minute baseline measurement under neutral light, the fluorescent lights turned off and the wall washers turned on for 60 sec showing one of the twelve predefined settings. Next, the room lighting turned back to its neutral light setting. This procedure was repeated until all twelve light stimuli were presented according to a fully balanced design to control for order effects. At the end of the experiment, the physiological measurements were stopped and each light stimulus was presented shortly once again to allow the participants to evaluate the stimulus with regard to arousal and valence on two pictorial 5-point scales and to report on possible associations that they had in an open question.



Fig. 1: Pairs of (predominantly) red, green and blue positive and negative priming pictures.

Table 1: Hue (H in degrees), Saturation (S) and Lightness (L^* in %) values of the 12 light stimuli.

Light stimuli (n=12)	Red		Gree	n	Blue	
	Saturated	Desaturated	Saturated	Desaturated	Saturated	Desaturated
L*=81%	H=21° S=2.3	H=21° S=0.8	H=162° S=2.3	H=162° S=0.8	-	-
L*=63%	H=21° S=2.3	H=21° S= 0.8	H=162° S=2.3	H=162° S=0.8	H=262° S=2.3	H=262° S=0.8
L*=54%	-	-	-	-	H=262° S=2.3	H=262° S=0.8

Results

Subjective Evaluation

For each color (red, green, and blue), we performed a repeated measures on the arousal and valence scores with Saturation and Lightness as within-subject factors and Priming Picture (positive or negative) as betweensubject factor. Five of these six analyses revealed no significant effect of Priming Picture, suggesting that priming with predominantly red, green, and blue colored pictures with a positive or negative emotional content does not affect the subjective evaluations to colored light stimuli. Therefore, the factor priming picture was left out further analyses.

Mean arousal and valence scores of the 12 light stimuli are depicted in Fig.2. Due to the incomplete design, three analyses were performed. Strong and recurrent effects were found for Saturation and Hue. First, the repeated measures on arousal and valence of the green and red stimuli with Saturation,



Fig. 2: Mean valence/arousal of the 12 light stimuli.

Hue, and Lightness as within-subject factors demonstrated that the saturated stimuli were judged significantly more arousing (F(1,39)=66.619; p<0.001) and less pleasant (F(1,39)=6.364; p<0.05) than the desaturated stimuli. Secondly, the repeated measures on arousal and valence of the 63%-lightness stimuli with Saturation and Hue as withinsubject factors revealed a significant main effect of Hue on arousal (F(2,38)=37.364; p<0.001) and on valence (F(2,38)=3.683; p<0.05). Post-hoc tests showed that the red stimuli were scored significantly less pleasant and more arousing than the blue stimuli. Finally, the repeated measures on arousal and valence of the blue stimuli only with Saturation and Lightness as within-subject factors showed that saturated blue light stimuli were rated to be more pleasant than the desaturated stimuli (F(1,39)=7.746; p<0.01).

Objective measures

From the recorded physiological data, nine measures (skin conductance level, skin conductance response, skin temperature, skin temperature slope, respiration rate, respiration depth, heart rate, heart rate variability, and respiration - heart rate coherence) were derived. None of the measures showed a significant effect in the repeated measures per color (red, green, and blue) with Saturation and Lightness as within-subject factors and Priming Picture (positive or negative) as between-subject except for a significant red priming picture effect on the coherence between respiration and heart rate. Because no effects were seen for the blue and green priming pictures, the priming effect on coherence was considered to be rather weak and was therefore ignored in further analyses.

Additional analyses provided only two significant effects. First, the repeated measures on skin conductance response (SCR) of the 63%-lightness stimuli with Saturation and Hue as within-subject factors revealed a significant main effect for Hue on SCR, indicating that red light stimuli triggered more SCR's per minute than blue light stimuli (F(2,36)=3.740; p<0.05). Secondly, the repeated measures on SCR of the blue stimuli with Saturation and Lightness as within-subject factors showed that SCR was higher for saturated light stimuli than for desaturated light stimuli (F(1,37)=9.873; p<0.005).

Conclusion

This study replicated the results of Rajae-Joordens (2011). More arousing and less pleasant evaluation scores were found for saturated than desaturated stimuli (except for saturated blue stimuli being more pleasant than desaturated blue stimuli), and for red compared to blue stimuli. In contrast with Rajae-Joordens, we observed significant physiological effects on the number of skin conductance responses (SCR), probably due to the substantially larger sample size of 40 instead of 20 participants. The SCR was higher for red compared to blue stimuli, and for saturated compared to desaturated stimuli. Thus, the SCR nicely corresponds with the scores on the subjective arousal scale.

Priming with predominantly green, red and blue colored pictures with a positivecalming or negative-arousing emotional content did not affect the subjective evaluations and physiological responses to colored light stimuli. Possibly, the priming pictures were not strong enough to evoke associative responses as described by Gerard (1958).

Participants mentioned that the red stimuli appeared unpleasantly saturated compared to the green and blue ones. This perceived saturation difference is likely due to the fact that the white point properties of the relative warm neutral setting of 4300K in-between the colored light stimuli was also used as reference white point to equate the colored light stimuli in the CIELAB color space. Consequently, the saturation levels of all light stimuli were set relative to this somewhat orange-reddish white point, making the red stimuli appear more saturated compared to the blue and green ones. This unforeseen difference in perceived saturation underlines the difficulty of equating saturation levels of colored light stimuli in a further completely dark room without any reference light.

In summary, whereas the priming pictures showed no effects in this study, consistent arousing effects of saturation on both subjective and objective measures were found. The observation of red light stimuli being more arousing than blue light stimuli is likely due to perceived saturation differences.

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Effects of Indoor Lighting on Depression Probability and Academic Performance in a Population of Turkish Adolescents

K. E. Sansal¹, B. Z. Edes², & A. Ogus Binatli²

¹ Bahcesehir University, Istanbul, Turkey ² Izmir University of Economics, Izmir, Turkey

Introduction

Previous research

There is an accumulating body of research evidence indicating that depression is a common and largely unrecognised mental health problem in Turkish adolescents (Eskin et al., 2008; Toros et al., 2004) and their peers worldwide (Frigerio et al., 2001; Saluja et al., 2004). While depression is not highly prevalent in prepubertal children, the incidence of this problem in children, especially in girls, increases substantially during the period following puberty (Kessler et al., 2001; Lewinsohn et al., 1994). One should be aware of the fact that overlooking or disregarding adolescent depression can have profound and tragic consequences. There is convincing evidence that it leads to serious social and academic problems (Frigerio et al., 2001; Saluja et al., 2004) and constitutes a major risk factor for substance abuse and suicidal behaviour (Kovacs et al., 1993; Saluja et al., 2004). Therefore, it is viable to deduce that both the diagnosis and treatment of adolescent depression is of vital importance.

Because of its high prevalence and detrimental effects, a concerted effort has been made to identify the major determinants of depression in adolescent boys and girls. A large number of empirical studies have provided a wealth of information on the association between adolescent depression and perceived social support, or more specifically, the feeling of being cared for, esteemed, loved and valued by others. It has been demonstrated that the perception of having inadequate social support from family members, friends and teachers increases the likelihood of depression in Turkish adolescents (Eskin et al., 2008; Yildirim, 2004) and their Western counterparts

(Kaltiala-Heino et al., 2001; Newman et al., 2007). In addition to the protective role of perceived social support, the influence of a variety of sociodemographic factors have been repeatedly reported in the literature. In most of the studies carried out on Turkish and non-Turkish adolescents, it has been found that parents' education, family size, parents' employment, family income and separation from both or one of the parents are directly related to the severity of depressive symptoms (Sund et al., 2003; Toros et al., 2004).

It has been demonstrated that, apart from vision, the lighting of interiors may have implications somatic for our and psychological well-being (see Boyce, 2003). This raises the question as to whether indoor lighting can be used effectively to ameliorate depression in adolescents and improve their quality of life. Even though it is currently hard to give a definitive answer to this question, there is suggestive evidence that indoor lighting conditions may affect adolescent depression. For example, by retrieving and analysing hospital records for over a 2-year period, Beauchemin and Hays (1996) compared the average duration of hospitalisation in a cohort of psychiatric inpatients who had been suffering from severe depression and assigned to "bright and sunny" rooms in a Canadian ward with that of a corresponding group of patients treated in "dull" rooms. The researchers observed that a plentiful supply of daylight could expedite significantly recovery. The discharge of the patients accommodated in the sunny rooms was almost 3 days earlier. This finding is supported by an analogous study of Benedetti and colleagues (2001) in an Italian facility. In accord with the others, they stated that the length of stay was

approximately 4 days shorter in a group of psychiatric inpatients hospitalised for bipolar depression in comparatively brighter and sunnier rooms. A methodologically similar study by Kecskes et al. (2003) is also wellworth citing in the present context. By scrutinising hospital records for over a span of 3 years, the researchers investigated the influence of season upon the average length of hospitalisation in a large number of depressive inpatients. The findings of Kecskes and colleagues were in line with those of the other research groups. The hospitalisation periods of both male and female depressives were comparatively shorter in summer. However, the significant difference was confined to the females older than 50 years of age.

It should be noted here that the abovementioned studies and a substantial portion of the research into the non-visual effects of indoor lighting has been conducted on healthy and patient adult populations. Therefore, there is a lack of knowledge about whether the conclusions drawn from the studies on adults are valid for children and adolescents.

Present research

To our best knowledge, there exists no empirical work that has been devoted to investigate the relationship between the lighting of indoors and adolescent depression. Accordingly, in an attempt to investigate and reveal whether there is an optimal indoor lighting condition for alleviating depressive symptoms and, as a direct consequence, improving academic achievement in adolescents, the present research was undertaken.

Methodology

Participants

In total, 275 9th-grade high school students, of whom 114 (41.5%) were female, were recruited to voluntarily participate in the study. The mean age of the participants was 14.7 ± 0.7 years (participants' age range, from 14 to 17 years). In order to minimise the confounding effects of prior knowledge or expectations on their self-evaluations, no information on the aim and possible

outcomes of the study was given to the participants before the completion of data collection.

Setting

The study was carried out in nine similar classrooms of a high school in Izmir, Turkey. Izmir is a large city located in the western extremity of Anatolia and has a typical Mediterranean climate. The classrooms were similar in size, interior décor and artificial lighting. They mainly differed from each other with respect to the location, number and transparency of windows, or in other words, the provision of daylight (Figure 1).



Fig. 1: Two different classrooms

Study protocol

Between the 22nd of March 2012 and 21st of April 2012, three data collections were executed at approximately 2-week intervals in order to assess participants' depressive symptoms by administering the Turkish version (Oy, 1991) of the Children's Depression Inventory (CDI; Kovacs, 1985). The CDI is a 27-item inventory that can be administered to children from 7 to 17 years of age. The items in the inventory are rated on a 3-point scale to report on the severity of the depressive symptoms experienced in the past 2 weeks. A CDI score is obtained by adding the scores for each item, and it can vary between 0 and 54. A score equal to or greater than 19 is considered to be indicative of depression.

Table 1: Determinants of the probability of depression

Variable	Coefficient	Standard Error
Gender (male)	-1.32*	0.49
Academic performance	-1.44*	0.36
Vertical illuminance	-0.0014*	0.0006
# of observations		740
Wald Test $x^2(3)$	7	7.37*

Note: * denotes the level of significance at 5 per cent.

Participants' grades on their examinations were obtained from the school administration in order to assess their average scholastic success in Turkish, history, mathematics, physics, chemistry and biology. Moreover, vertical illuminance levels at sitting eye height (i.e., at 120 cm) in each classroom were measured¹ on the days of data collection.

Statistics

In order to estimate the effects of lighting conditions in the classrooms on the probability of depression, we employed a probability model based on the logistic distribution, namely the panel logit model. As a complementary analysis, in order to investigate the effects of the lighting conditions on academic success, a linear regression on the cross-section of the students was estimated. All calculations regarding the statistical analysis were carried out with the STATA (version 11.1; STATA Corp., College Station, TX, U.S.).

Results

The regression results presented in Table 1 are based on the panel data from all three administrations of the depression inventory and measurements of vertical illuminance. It is evident from the table that the probability of being depressed (i.e., having a CDI score greater than 18) is significantly lower for male participants. Furthermore, it can be



Fig. 2: The probability of depression for the participants having low academic performance

deduced that there is a causal relationship between depression and low academic performance. The probability is significantly higher for the students having lower examination scores. Moreover, it is reasonable to infer from the table that the level of illumination reaching the eye has a profound effect on the probability of depression. The higher the illuminance, the lower the probability of depression. The results are summarised in Figure 2.

Table 2: Determinants of academic performance

Variable	Coefficient	Standard Error		
Gender (male)	0.21**	0.11		
Vertical illuminance	N.S.			
Intercept	1.53*	0.26		
# of observations		268		
F(2, 263)	3	3.03*		

Note: * and ** denote the level of significance at 5 and 10 per cent, respectively.

associations between The vertical illuminance and academic achievement, as well as gender, were also investigated. Average vertical illumination levels for each classroom were computed based on all three illuminance measurements. A cross-section sample of 263 students in all nine classrooms was obtained. The regression results are reported in Table 2. Although it is possible to infer from the table that male participants exhibit higher academic performance on average, it is not viable to deduce that there is a significant relationship between

¹ It is relevant to mention here that, during the illuminance measurements, the occupants of the classrooms were not using artificial lighting due to adequate illumination from the classroom windows.

participants' scholastic performance and vertical illuminance at eye level.

Discussion

It is beyond the scope of this paper to full-fledged analysis undertake а of depression probability by taking the effects of sociodemographic factors and social support into consideration. The aim of this paper is to reveal whether or not indoor luminous conditions can influence depression and academic performance in adolescents. In the light of our findings, it does not seem unreasonable to suggest that the amount of light, particularly natural light, reaching the eye is likely to be an important factor in altering depressive feelings, but not performance, in adolescents. What is also possible to discuss here that there may be a threshold illuminance level (i.e., approximately 1,400 lux) above which no further benefits are seen.

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Experiencing LED: Lighting: New Form and Experiential Qualities Emerging in Lighting Systems using LED

K. Y. Petersen¹, O. Kristensen¹, & K. Søndergaard²

¹ IT University of Copenhagen, Copenhagen, Denmark ² The Royal Academy of Fine Arts, School of Architecture, Copenhagen, Denmark

Introduction

The project investigates what new forms qualities of light emerge and from technologies such as LED, with a particular focus on basic form qualities and parameters. Existing linear functional understandings of the relation between light source, light flow, reflection and visibility is challenged by understandings, relational where the materiality and visibility of the light emerge through mutual influences between several adaptive and transformative elements.

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Fig. 1: Linear LED cluster. Screenshot from the pixel visualization software.

Investigations into pixel patterns

The first investigation looks into the qualitative parameters related to the pattern of pixels. Most LED products are produced with grid orders or similar systematic and repetitive patterns. We have developed a software tool that allows us to adjust pixel organization, size and distance, and sense the impact of different organization of pixels on perceptual and form qualities. We investigate the organization of pixels, as patterns of material light and as experience light perception.

The systematically square-grid arranged pixel pattern evokes extensive reaction from the perceptual system. A pulsating interference pattern is evoked and the eyes are highly occupied with this stressful task. This reaction seems to appear within a rather large range of pixel scales, actually the whole rage we where able to display on our 56" LED monitors. That is a range from 20x30 pixel to 4x6 pixel within the screen size. Further experiential tests will investigate to what extent there are limits and border phenomena in higher and lower resolutions. These resolutions are similar to the experience of light armatures in office buildings, which often is structured into rigid grid patterns, and many other large scale light designs, where the distance to the lights of the experiencer scale the experience of the pattern into the same resolution as our screen prototype.

When the pixel pattern is organized by perlin noise (Perlin 2002), all perceptual artifacts disappear. In-between these to extreem positions (the rigid grid structure and the random pattern generated by the perlin noise) is a very interesting qualitative parameter, highly relevant in the design of LED based lighting installations, which invite to pixel based designs and distributed light sources.

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

S. H. Wan,¹ J. Ham,¹ D. Lakens,¹ J. Weda², & R. Cuppen²

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 will lead to lower lighting 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 dvnamic conditions). Participation lasted approximately 40 minutes, and participants were paid \notin 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 wallwashers (ColorGraze Powercore linear LED, Philips Lighting). We used two rows of wallwashers 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 ($\alpha = .96$). 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 ($\alpha = .77$), liveliness (α = .76), tenseness ($\alpha = .84$) 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 After that sensors. 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 bv 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 reported (psychological) condition on 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 stressrecovery. 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.

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Le Cube: designing interactive lighting furniture in modern lighting systems to enhance user experience

D. Le, S. Offermans, & H. van Essen

Department of Industrial Design, Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

Modern lighting platforms, based on LED technology, consist of numerous, highly dynamic, light sources and embedded sensors that are interconnected and able to communicate. These light sources will be embedded in areas where we live and work and in the objects we use and interact with. The user experiences the resulting lighting. We have developed a living lab, within a break out context, which contains such a lighting platform. We believe the challenges for such modern lighting platforms are threefold. The first challenge arises in the development of valuable applications; in other words, how do we support people through lighting? The second challenge is in the development of platform elements; what "shape" have the "luminaires" that make up the platform, and how do they communicate and work together? Finally there is a challenge in user-system interaction; how will people communicate their wishes and intentions with the system?

Design of Le Cube

Le Cube is a piece of lighting furniture that aims to address the above challenges through design. Le Cube was specifically designed to improve user experience in breakout contexts at modern offices. It resulted as a tangible light cube and as an adaptive platform that transforms a regularsmall coffee table into an ambient lighting element. Le Cube is able to connect with other lighting nodes of the breakout area and as such seamlessly fits in and collaborates with the lighting platform. This makes it possible to change the atmosphere of the room instantly, enabling the people in the room to relax from work, to be inspired for creativity or to connect with each other. The design process of Le Cube contributes to an understanding of how new lighting experiences are potentially packed into everyday furniture.

Discussion

Users appreciate the possibility to run different applications on such an object so they can choose an appropriate one for their preferential contexts. The interactive object attracts attention and connects people within the room. Yet Le Cube is more than an attractive eye catcher for end-users. As an active platform element, Le Cube contributes to the breakout room as a smart space. Le Cube can be used as a natural and tangible object to interact and control different lighting settings in the room. Moreover, it promotes and enhances the opportunities a platform offers. Developers can easily generate new functionalities or applications in the table or include the properties of the table into other apps that run on the platform. Concluding, Le Cube is a supportive element to enhance specific breakout experiences and also opens a new design space in interior lighting design on experience design and interaction design.



Fig. Le Cube sample applications: campfire, interactive blob, random blob and rainbow

Effects of Ageing on Atmosphere Perception

A. Kuijsters¹, J. Redi¹, B. de Ruyter², P. Seuntiëns² & I. Heynderickx¹²

¹ Delft University of Technology, Delft, the Netherlands ² Philips Research, Eindhoven, the Netherlands

Introduction

The advent of LED technology radically increased the potential of lighting for improving human well-being. Light of various colors and intensities can be created at any place and time, allowing a variety of decorative and ambience lighting effects. When combined with functional lighting, these effects can be used to create affective ambiences that can more easily address the needs of occupants in the room.

Lighting-based ambiences be can exploited to the benefit of the (growing) elderly population accommodated in care centers. Especially at the moment of relocation, elderly can experience anxiety, because they realize that they are in the last stage of their life, or sadness, because they miss family, friends or pets (Lee, Woo, & Mackenzie, 2002). Reducing these negative feelings through the action of positive ambiences in the room (e.g., a pleasant high arousing ambience to compensate sadness, and a pleasant low arousing ambience to decrease anxiety) could improve the elderly quality of life and might reduce the demands on the nursing staff. This solution has already been shown to have some potential for patients affected by dementia (Riemersma et al. 2008).

The first step towards our goal is to determine how elderly experience the affective meaning of ambiences. We refer here to this experience as atmosphere perception. Atmosphere differs from mood; it does not represent the affective state of a person, but rather the affective state of an environment (Vogels, 2008). As such, an atmosphere describes the potency of an ambience to change a person's mood. Independent of a person's affective state when entering a room with a specific atmosphere, the affective state of the

ambience can be almost immediately recognized (Vogels, 2008). This atmosphere should have, on the longer term, a positive influence on the affective state of the people that are immersed in the ambience.

Ageing effects on the visual system can influence the experience of the ambience. The absolute sensitivity to light declines approximately threefold over the course of a lifetime, because of a reduction of the pupil size and increased lens absorption (Johnson, 2005). Also color perception declines from the age of twenty; especially the perception of short wavelengths (blue) are affected by age related effects as yellowing of the lens and the selective loss of short-wavelength sensitivity cones (Johnson, 2005). In line with these age related visual impairments, Knez and Kers (2000) found that older people judge the room illumination as less bright and as warmer compared to younger people, regardless of color temperature of the light.

Several researchers argue that different age groups have different attitudes towards colored lighting. Yildirim and colleagues (2007) revealed that older customers had more negative atmosphere perceptions of colored interiors. They argue that as age and experience increase, a more critical attitude is displayed. Also Knez and Kers (2000) argue that different age group share different conceptions about the indoor lighting.

For our purposes, we need to understand how elderly perceive the affective meaning of ambiences, and to do so we compare their atmosphere perceptions with that of younger people. We begin our research starting from ambiences created by light designers. Designers were asked to create two pleasant low arousing ambiences (i.e., cozy and relaxing) and two pleasant high arousing ambiences (i.e. activating and exciting) for a modern living room and with younger people in mind (Seuntiëns & Vogels, 2008). By means of Vogels' Atmosphere questionnaire (2008) the ambiences are first evaluated by younger people to check the light designers' input. Thereafter, a group of elderly participants also evaluates the ambiences with the same methodology. We report here the results of this experiment, highlighting similarities and differences in atmosphere perception between elderly and younger people.

Experimental Design

Two separate experiments were conducted; one with younger participants and one with elderly. Both experiments had the same within-subject design; with the four ambiences (cozy, activating, relaxing and exciting) as independent variables and the scores of the Atmosphere questionnaire as dependent variables.

Our participants were immersed in the ambience and then asked to fill in the Atmosphere questionnaire. The questionnaire measures perceived atmosphere on four dimensions: coziness, liveliness, detachment, and tenseness. It uses seven-point Likert scales, ranging from totally not applicable (-3) to totally applicable (3). Participants were asked to base their scores on the atmosphere of the complete room. The ambiences were shown for as long as it took the participants to rate them and were randomized between participants, with a neutral ambience in between. On average, it took the participants around four minutes to complete the questionnaire.

Participants

In the first experiment fifteen participants were involved (8 females and 7 males), aged between 19 and 30 years. In the second experiment twenty-one elderly participated; 12 females and 9 males. Their age ranged between 65 and 88 years. All participants were native Dutch speakers and had no colorblindness.

Experimental room

The experimental room was located at the Philips ExperienceLab and furnished as a living room. The room size was 6x4x3 meters. The color of the walls was white and



Fig. 1: An overview of the installed luminaires in the experimental room

the ceiling had an off-white (i.e. ivory white) color. The floor consisted of dark grey carpet patches. The windows were blinded from the outside in order to prevent influences of natural light during the experiments. On the inside, the windows were covered by low chromatic curtains. Furthermore, a black coffee table, white sofa and a white chair were set around the center of the room. Underneath the coffee table an off-white carpet was placed, and a black television cabinet with a black 42" television was placed on the wall against the sofa. Finally, a black dinner table with four chairs was placed against the wall on the left-hand side of the sofa.

Installed luminaires

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

Decorative lighting was provided by three Philips Living Color lamps. Two were placed on each side of the television cabinet and one in the lower left corner. A table light consisting of red, green and blue LED strips was mounted underneath the coffee table and illuminated the floor underneath the coffee table. Finally, a Gemini table lamp, consisting of red, green and blue LEDs illuminated the ceiling above the dinner table.

Stimuli

Four different ambiances were created by light designers reflecting a cozy, relaxing, activating and exciting ambiance (see Figure 2). For details on the light characteristic of the four ambiences see Table 1 and (Seuntiëns & Vogels, 2008).

Table 1:The illuminance level, color temperature and the use of hues in the ambiences

Ambience	Illum [lx]	CT [K]	Hue pairs
Cozy	Low	2700	Orange, blue
Activating	High	4000	Cyan, blue
Relaxing	Low	2700	Green, blue
Exciting	High	4000	Random colors
Neutral	Medium	3400	Only white

Results

Quantitative data

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

For both groups of participants we obtained acceptable to good reliabilities (values ranging between .67 and .89 for elderly, values ranging between .75 and .89 for younger participants).

Figure 3 presents the average atmosphere scores on the four ambiences for both the younger people and the elderly; separated for each of the four atmosphere dimensions.

For the younger people the 'cozy' ambience received the highest coziness scores, followed by the 'relaxing' ambience. The 'activating' and 'exciting' ambiences received the lowest coziness scores. The Wilcoxon signed-rank test on the coziness dimension revealed a significant difference between the 'cozy' ambience and the three ambiences: 'relaxing' other (z=-3.02,p=.003), 'activating' (z=-3.35, p=.001), and 'exciting' (z=-3.42, p=.001). In addition, also the difference between the 'relaxing' ambience and both the 'activating' (z=-2.50,p=.012) and 'exciting' (z=-2.11, p=.035) ambience was significant for the coziness dimension. For the elderly the 'cozy' ambience received the highest coziness scores in line with the results of the younger



Fig. 2: Ambiances created by light designers; reflecting a relaxing (a), activating (b), cozy (c) and exciting (d) ambiance

people, but the scores were just above neutral. Only the differences between the 'cozy' ambience and both the 'relaxing' (z=-2.44, p=.015) and 'exciting' (z=-2.58, p=.010) ambience were significant for the coziness dimension assessed by the elderly.

Both the 'activating' and 'exciting' ambiences were scored high on liveliness by the younger participants; the 'cozy' and 'relaxing' ambience received low liveliness scores. For the liveliness dimension a significant difference was found between the 'activating' ambience and both the 'relaxing' (z=-3.01, p=.003) and 'cozy' ambience (z=-2.98, p=.003). Furthermore, a significant difference between the 'exciting' ambience and both the 'relaxing' (z=-3.21, p=.001) and 'cozy' (z=-2.48, p=.013) ambience was found.

Similar results were found for the elderly; the 'activating' ambience received the highest liveliness scores followed by the 'exciting' ambience. The scores were however lower than those obtained by the younger people. The 'activating' ambience was rated significantly different from both the 'cozy' (z=-2.77, p=.006) and 'relaxing' (z=-2.94, p=.003) ambience on the liveliness dimension. Also the liveliness of the 'exciting' ambience was scored significantly different from both the 'cozy' (z=-2.33, p=.020) and 'relaxing' (z=-2.16, p=.031) ambience.

All four ambiences were scored below neutral on the tenseness dimension by the younger participants; the exciting ambience received the highest scores. Only the



Figure 3. Average atmosphere scores on the four ambiences for both age groups separated for the four atmosphere dimensions

difference between the 'exciting' ambience and both the 'cozy' (z=-3.31, p=.001) and 'activating' (z=-2.29, p=.022) ambience were significant.

Also for the elderly all ambiences were scored below neutral on tenseness. No significant differences were found.

The activating ambience received the highest detachment scores from both age groups. The analysis revealed a significant difference between the 'activating' ambience and three other ambiences for both younger people: 'cozy' (z=-3.30, p=.001), 'relaxing' (z=-3.17, p=.002), and 'exciting' (z=-3.31, p=.001), and elderly: 'cozy' (z=-3.55, p < .001) 'relaxing' (z=- 3.01, p=.003), and 'exciting' (z=-3.30, p=.001).

Significant differences between the scores of the younger people and the elderly were investigated with the Mann-Whitney test. The coziness scores for the 'cozy' ambience were significantly different between the younger and elderly participants (z=-2.11, p=.035). For the exciting ambience a significant difference was found between the scores on the liveliness dimension (z=-2.36, p=.018). All other differences were found to be non-significant.

Qualitative data

After the experiment, the elderly were allowed to comment on the ambiences presented. Most elderly reported that the 'relaxing' ambience was too dark and they disliked the green blue color combination. Several elderly commented that the use of different colors in the 'cozy' and 'relaxing' ambiences gave them a restless feeling. Also the blue light above the table in both ambiences was perceived as cold and uncomfortable. Another remark of the elderly concerned the 'exciting' ambience; they found the ambience to be unsuited for the elderly population.

Discussion

The ambiences, with the exception of the relaxing ambience, were well recognized by the younger people. The 'cozy' ambience received high scores on the coziness dimension, while the 'activating' and 'exciting' ambience received high liveliness scores.

The ambiences were, however, less well recognized by the elderly population. The 'cozy' ambience received the highest coziness scores; the scores were however just above neutral and significantly lower than the scores of the younger participants. The liveliness scores of both the 'activating' and 'exciting' ambience were lower compared to those of the younger people; for the 'exciting' ambience this difference was found to be significant.

The qualitative data gave some insights why the ambiences were less well recognized by the elderly. The relaxing ambience was perceived as too dark. This might be caused by a decline in the sensitivity to light in the elderly population (Johnson, 2005). Also the use of more than one color in the relaxing, cozy and especially in the exciting ambience was perceived as restless and unsuited for the elderly population. This conclusion is in line with Knez and Kers (2000), who found that groups have different age different conceptions about the room light, and with the findings of Yildirim et al. (2007), who showed that older customers have more negative atmosphere perceptions of colorful interiors. Determining the reasons behind this discrepancy and precise design guidelines for the design of lighting atmospheres for elderly are still open research topics and will be addressed in future research.

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Effect of Eye Movements on Perception of Temporally Modulated Light

I. M. L. C. Vogels, & I. Hernando

Philips Research, Eindhoven, the Netherlands

Introduction

LEDs are considered as the lighting technology of the future. Although LEDs offer many advantages, the perceptual quality of the light is not always as high as that of traditional light sources. LED based systems usually produce temporal fluctuations in the amount of light emitted, either because they are operated by pulse width modulation to control heat or they are directly driven by AC main voltage. The frequency of the light modulation can vary but is generally above the critical flicker fusion threshold of about 100 Hz (Kelly, 1961). Hence, the temporal changes are not directly visible. Under circumstances, certain however, our perception of the environment can be affected by this flickering light. First, moving objects might appear to move discretely instead of continuously, which is called the stroboscopic effect (Vogels et al., 2011). Second, a point light source might appear to exist of a series of dots, called a phantom array, when rapid eye movements (saccades) are made (Hershberger and Jordan, 1998). This can be observed, for instance, when driving behind a car with LED rear lights at night. A trail of lights can be experienced during each eye movement.

The origin of the perception of a phantom array is not fully understood yet. It is generally accepted that the perceived location of an object is determined by the summation of the retinal position of the object and an extraretinal oculomotor signal about the eye position. The mislocalization of a flickering light source during a saccade reveals that this process is not always functioning perfectly. Hershberger et al. (1998) suggested that the extraretinal signal does not correspond to the actual eye movement but it develops at a rate slower than the saccade. However, Watanabe et al. (2005) state that the localization of objects around the time of a saccade is more complicated and proposed a two-stage localization model.

Currently, only limited knowledge is available about the conditions in which the phantom array is visible. Hershberger and Jordan (1998) found that the pattern can be observed at frequencies as high as 500 Hz (the maximum frequency tested) for a light source at a luminance of 50 cd/m^2 and a visual angle of 0.2°. Recently, Roberts and Wilkins (2012) found that the maximum frequency to detect the occurrence of a phantom array for a vertical line on an oscilloscope at a luminance of 150 cd/m^2 was about 2000 Hz for saccadic amplitudes of 20-40°. Another experiment showed that the pattern of lines was less visible at smaller modulation depths of the modulated light. The pattern became invisible at modulation depths smaller than 10% for a square wave at 120 Hz.

In order to design LED based lighting systems that are experienced as pleasant, more knowledge on the perception of flickering light is needed. The aim of this paper is to investigate the visibility and annoyance of phantom patterns when making voluntary saccades across a light source that generates temporally modulated light. Different parameters of the modulated light were studied: beam size, light level, frequency and duty cycle (i.e. the time that the light is on as a fraction of the total time of one cycle). It is hypothesized that the phantom effect becomes less visible at a larger beam size, lower light level, higher frequency and larger duty cycle.

Method

Apparatus

A commercially available lamp (Elation Spot Opti White) was modified such that the



Fig. 1: Experimental setup

light level, frequency, duty cycle and waveform of the light could be controlled by a function generator. The lamp consisted of 24 white LEDs and was mounted in the front side of a closed box. A holographic diffuser $(10^{\circ} \times 95^{\circ})$ was placed at 20 cm from the light source in order to make a visually uniform light spot. A black cardboard with a small vertical groove was placed in front of the diffuser to make a vertical line of light with sharp edges. A second holographic diffuser (40° x 10°) was placed at different positions from the light source to make the edges of the stimulus more gradual.

The system was placed at the back of a larger black box in order to eliminate undesired visual references that could affect the visibility of the phantom images. At the open front size of the box a chin rest was placed at a distance of 75 cm from the light source to fixate the head of the participant during the experiment (see Figure 1).

Stimuli

The stimulus was a temporally modulated vertical line of light. The transition of the edges could be modified by placing a diffuser at different distances from the light source. As a result, the width of the stimulus, i.e. the distance between the two points at which the light level is half the maximum light level, corresponded to a visual angle of 0.5° (small), 1° (medium) and 2° (large) at a viewing distance of 75 cm (see Figure 2). The light generated by the light source varied over time with a square waveform. The duty cycle of the wave was 0.2, 0.5 or 0.8. Four frequencies were tested: 200 Hz, 400 Hz, 1000 Hz and 3000 Hz. These values were chosen such that people could not perceive flicker. The maximum frequency was determined by the highest frequency that could be generated by the system. The



Fig. 2: Luminance profiles of the small, medium and large beam size.

average luminance level of the wave was 64 cd/m^2 (low), 2000 cd/m^2 (medium) or 10000 cd/m^2 (high). The luminance levels were measured with a Topcon BM-7 colorimeter at the center of the light stimulus. At the low luminance level the stimulus was still visible, the high luminance level was the maximum value that could be made, and the medium luminance level was the perceptual medium between the two extremes.

Design

The experiment used a within subject design with visibility of the phantom effect as dependent variable and beam size (small, medium, large), luminance (low, medium, high), frequency (200, 400, 1000, 3000 Hz) and duty cycle (0.2, 0.5, 0.8) as independent variables. A pilot test revealed that the effect was not visible for low and medium luminance levels at a large beam size. Therefore these conditions were not included in the experiment. From the selected conditions, two full designs could be created. Design I contained all combinations with a small and medium beam size, resulting in a 2 (beam size) x 3 (luminance) x 4 (frequency) x 3 (duty cycle) design. Design II contained all combinations at a high luminance level, resulting in a 3 (beam size) x 4 (frequency) x 3 (duty cycle) design.

Participants

Ten males and five females, aged between 22 and 45 years, participated in the experiment. All participants had to fulfill a number of conditions: normal or corrected to normal visual acuity, no glasses, not suffering from epileptic seizures or migraine and able to perceive phantom images when extreme conditions are presented (see procedure).



Fig. 3: The percentage of responses in each of the response categories, as explained in the text, for the data of Design I.

Procedure

The participant was seated in front of the box with his/her chin on the chinrest in a dark room. In order to test if the participant spontaneously saw the phantom array, a stimulus with a small beam size and a high luminance was presented. The phantom array was expected to be most visible at these values. Participants were asked to make rapid eye movements from one side of the box to the other side of the box, corresponding to an amplitude of about 40°. Four questions were asked similar to the questionnaire of Hershberger and Jordan (1998):

- 1. Each time you move your eyes do you see one line or more than one line?
- 2. Do all the lines appear in one region of space or do they appear to be spread out?
- 3. Is the spatial arrangement of the lines random or regular; that is, do you see a regular pattern such as a line of lines?
- 4. Is the pattern of lines vertical as in up and down or horizontal as in side to side?

Only if participants saw multiple vertical lines ordered horizontally, the experiment was continued. All participants succeeded this test. Then a short training session was presented to get the participant familiar with the range of stimuli and the rating scale. Each time a new stimulus was presented, the participant was instructed to look at the stimulus for a few seconds to adapt the eyes, make a number of large eye movements across the stimulus and evaluate if the phantom array (i.e. the appearance of multiple lines) was (1) imperceptible, (2) perceptible but not annoying, (3) slightly annoying, (4) annoying or (5) very annoying.

After the training session, three test sessions were presented. In each session, all conditions for one beam size (i.e. one distance of the diffuser plate) were shown. The presentation order of the three beam sizes was randomized across participants as well as the stimuli within one session.

Results

Since the 5-point response scale is an ordinal scale, meaning that the items on the scale describe an order but the distance between successive items does not have to be equal, an ordered logistic regression analysis was used to test for significant main and interaction effects. This was done for each experimental design separately. Only two-way interaction effects could be calculated.

Design I

Design I consisted of all conditions with either a small or a medium beam size. Figure 3 shows the distribution of responses for the different levels of beam size, luminance, frequency and duty cycle.

Figure 3 shows that the number of "imperceptible" responses increases when the beam size becomes larger. At the same time, the number of responses in the categories "imperceptible but not annoying", "slightly annoying", annoying" and "very annoying" decreases. This means that the phantom effect becomes less visible as the beam size increases. Similar conclusions can be drawn for the other variables. The phantom effect becomes less visible when the luminance level decreases and the frequency increases.

An ordered logistic analysis (χ^2 =283, df=10, p<0.001) showed a significant main effect of beam size (p<0.001), luminance (p=0.025) and frequency (p<0.001). The effect of duty cycle was not significant (p=0.247). In addition, the interaction effects between beam size and frequency (p<0.001) and between duty cycle and frequency (p=0.009) were significant.



Fig. 4: The percentage of responses in each of the five response categories, as explained in the text, for the data of Design II.

A closer look at the data revealed that the interaction effects are caused by the fact that the phantom array was not visible to most participants at the highest frequency independent of the other variables. At lower frequencies a clear effect of beam size and duty cycle could be observed.

Design II

Design II consisted of all conditions with a high luminance level. Figure 4 shows the distribution of responses for the different levels of beam size, frequency and duty cycle. The phantom effect becomes less visible when increasing the beam size, frequency and duty cycle of the light.

An ordered logistic analysis (χ^2 =93.6, df=6, p<0.001) revealed significant effects of beam size (p<0.001), frequency (p<0.001) and the interaction between beam size and frequency (p<0.001). The effect of duty cycle (p=0.062) and the interaction between duty cycle and frequency (p=0.061) almost reached the significance level of 0.05.

Discussion

This study demonstrates that the visibility of an array of light sources when rapid eye movements are made across a flickering light source depends on several parameters, such as the size, light level, frequency and duty cycle of the modulated light. The phantom array is most clearly visible at a small light source with sharp edges. For a wider stimulus with soft edges the effect is much less pronounced. It would be interesting to investigate if this was due to the width of the stimulus or the slope of the light transition. We assume that both aspects play a role, as the visibility is probably related to the contrast of the resulting phantom array. This means that only for applications using small light sources it is important to take the phantom effect into account.

Roberts and Wilkins (2012) found that the maximum frequency to observe the phantom effect was about 2000 Hz. Our study showed that the maximum frequency depends on other stimulus parameters. For instance, the phantom array was visible at 1000 Hz for the small light beam but not for the wider stimulus. Therefore, guidelines or regulations for flickering light should not only take the modulation frequency into account. A more complicated model is needed to fully describe the effect. Such a model should also include the modulation depth and probably the color of the light.

For practical applications, the chance of being annoyed by the phantom array should be as low as possible. Preferably, the viewing angle of the light source should be significantly larger than 2°. When small light sources are used in a dim environment, such as the tail lights of a car, the luminance should be lower than 64 cd/m² and/or the frequency should be larger than 3000 Hz. It is expected that the acceptable luminance level will be higher when the ambient light level is increased.

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Daylighting and Cognition: Experimental Studies on Working Memory and Attention in Clerical and Educational Contexts.

J. M. Monteoliva¹, R. G. Rodriguez¹, A. E. Pattini¹, & M. S. Ison²

¹ Laboratorio de Ambiente Humano y Vivienda, INCIHUSA – CONICET, Mendoza, Argentina ² Grupo de Psicología Evolutiva y Educacional, INCIHUSA - CONICET, Mendoza, Argentina

Introduction

This paper introduces our interdisciplinary research on the influence daylight in human cognition, specifically in working memory and attention in two cognitive demanding contexts where we spend several hours during our lifespan: office and school environments.

Theoretical Framework

Humans are able to face novel situations and to adapt to changing conditions in a flexible way thanks to a set of cognitive skills called *executive functions* such as the *memory* and *attention*. The close relationship between these constructs arises in *working memory* (WM).

Attention involves directed and selective perception, interest in a particular source of stimulation, or concentration on a task (Van Zomeren & Brower, 1994). Its capacity is gradually developed from infancy to adulthood, but its activity is not only confined to regulate information inputs, it is also involved in processing the same information (Cooley & Morris, 1990). There is evidence of a third neuro-physiological system, the attentional system with the same status that the motor (efferent) and sensory (afferent) systems (Posner & Petersen, 1990). Theoretical and clinical interest in these attentional based in its processes is importance in learning development processes.

The concept of short-term memory in the last 30 years has expanded from a passive limited store to a more complex and active tripartite system that handles and processes information, known as Working Memory (Baddeley and Hitch, 1974). It is defined as a system that temporarily maintains and manipulates information, involved in cognitive processes such as language comprehension, reading and reasoning.

Study I: Clerical contexts

The introduction of Information and Communication Technologies (ICT) in offices added a constant cognitive processing that might be beyond human load capabilities. Working memory plays a crucial role in ITC work, retaining the incoming information, changing and renewing the contents of information accordingly to the operation and the processing. Previous studies investigated WM variations in ICT work (Shieh et al., 2005). The effect of indoor lighting on cognitive performance via mood was studied by Knez (1995) and Vanderwalle et al. (2007) found non-visual effects on working memory and arousal from different monochromatic light exposures.

However, the role of glare sources as attention distractors, and their impact on cognitive performance is lacking in the literature so far. The hypothesis behind this investigation is that glaring lighting conditions might be related to non-visual effects affecting ICT operators' cognitive efficiency and effectiveness.

Methods

Glare caused by natural lighting is usually studied in dark chambers lit with devices emulating a window and we used the same strategy test our hypothesis. The to experiment took place inside the CCT experimental light laboratory at CONICET-Mendoza, Argentina. We measured cognitive efficiency and effectiveness on 25 volunteers (mean age 30.16 years old; SD 3.95), with normal or corrected vision and without any medical treatment.

Cognitive efficiency was assessed by means of RTLX (Byers and others, 1989), a multidimensional scale that uses six dimensions to assess mental workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. Cognitive effectiveness was measured as Working Memory Span with the Reading Span Task (RST) [Daneman & Carpenter, 1980], a complex performance measure that correlates with a wide range of high order cognitive tasks present in ICT work [Conway and others, 2007]. We developed a digital version of RST. The subjects were required to read aloud at their own pace sentences presented on screen and to remember the last word of each sentence for later recall. Increasingly larger groups of sentences were presented until the subject failed to recall all three groups of a given size. To include processing besides storage, the subjects also had to indicate whether any word of the sentence had a spelling error or not.

We created a large area (1 m x 1.5 m) non - uniform luminance glare source with 54 incandescent lamps and a diffusing screen. A three factors at two levels full factorial experiment was designed. The factors were: (i) Luminance contrast between the task and the source. In clear sky conditions, with sun presence in the visual field, the luminance can reach values of 10^5 cd/m² near the solar disc. We considered unnecessary to replicate those levels because glare sensation depends on the luminance the visual system is adapted to; therefore it is a relative concept. (ii) Apparent size of the source in steradians: The lower level was 10^{-2} sr and the higher level was 6.6×10^{-2} sr to avoid a raise of adaptation luminance by the source. (iii) How the task was done: In the prosaccadic condition the participants had to shift their vision between the source and the computer screen, a visually demanding scenario in terms of visual adaptation. In the antisaccade condition, the subjects had to fixate in the computer screen, ignoring the glare source.

To characterize lighting conditions on each treatment we built luminance maps from HDR images and calculated Daylight Glare Index (DGI) with *Evalglare* (Wienold and Christoffersen, 2006). We assessed the participants' subjective sensation of glare with GSV scale (Hopkinson, 1972).

Results and Discussion

We performed a factorial ANOVA and found higher scores of GSV in the prosaccadic scenarios (p-value 0,001). Glare sensation was directly proportional to source size (p-value<0,0001) but the largest effect was caused by luminance: higher glare sensation votes were associated with higher luminance contrasts (p-value<0,0001). Interaction effects between source size and luminance were also found (p-value<0,0001).

The factorial ANOVA showed no significant effects (p-value>0.05) of the experimental factors on cognitive efficiency: The RTLX method failed to predict variations in cognitive efficiency caused by the glare source. Our results showed that cognitive effectiveness was statistically significant lower (p-value<0,05) in those treatments where the volunteers had to shift their sight between the glare source and the task. The source acted as a powerful environmental distractor by reducing WM capacity of the subjects. This result links WM span with the attention management capabilities of the individuals (Jarrold and Towse, 2006). Finally, two effects were not statistically significant but showed a trend: Luminance (p-value 0,103) and the interaction between task and luminance (pvalue 0,127).

Study II: Educational contexts

Daylight is one of the classroom's most critical environmental factors (Phillips, 1997) and has been strongly associated with performance and health of school children (Wei, 2003). The relevance of the visual environment in the classroom, is given by its influence on a student's ability to perceive visual stimuli and to affect his mental attitude, and hence his performance, learning, attitudes and value judgments (Heschong Mahone Group, 1999). For instance, children with attentional dysfunction have different performance in classrooms with different light sources (Antrop, Roeyers & De Baecke, 2005).

In our context, one of the most significant risk factors for school failure is the attentional dysfunction in childhood; issues that affect academic performance and social development. Considering this, the assessment of attentional skills in children with valid, reliable and suitable methods for our school population is relevant to achieve a precise diagnosis and to plan adequate intervention programs (Ison and Anta, 2006). In this context we present an interdisciplinary study, part of a new research line relating lighting and attention that began with pilot studies conducted by Dr. Ison and Dr. Pattini (2009), and continued in greater depth as part of a doctoral thesis in progress (Monteoliva, 2010). Our main objective is to find a correlation between daylight and attentional skills in educational environments. The following field experiment was conducted during morning shift in November 2011 (presummer) to test our hypothesis that "classrooms with daylight source might attentional efficiency". improve The experiment took place at Republic of Chile primary school in Mendoza, Argentina.

Methods

The sample size was 24 third grade primary students (14 men and 10 women) aged between 8 and 10 years old (mean 8.78), half of them from division A and half of them from B division. Due to the high rate of absenteeism in marginal institutions like this one, the initial sample was oversized (n= 36) anticipating participant loses during the study. We worked with two independent groups (divisions A and B) to randomize the conditions of the independent variable (avoiding potential bias caused by learning and adaptation effects), and to develop the experiment in the habitual contexts of the participants. Attentional skills were assessed with was the Differences Perception Test (Thurstone, "FACES" 1941) and its was evaluation parameter "attentional efficiency." This test has 60 main feature graphic elements, each consisting of three schematic drawings of faces (mouth, eyes, eyebrows and hair rendered with basic strokes), two of which are equal. The goal is

to determine the different face and cross it off. The test is applicable from 6 to 7 years old. In its original version the score was represented by a raw score of the total number of hits. For the attentional efficacy parameter, we evaluated the accuracy a child could discriminate stimuli within a set of similar looking stimuli by means of errors of omission and commission. This parameter allows assessment of individual performance on tasks that combine sustained and selective attentional skills, which is the *dependent variable* of the study.

The *independent variable* was the type of primary lighting source. We selected two classrooms of the institution with the same morphological characteristics (8.1 m x 6.5 m x 3.8 m), each one lit by a different light source: (a) Natural and (b) Artificial. For condition (a) the study was based on predictive dynamic daylighting in these spaces, orientation North-South, with windows in both orientation; 5600°K. Condition (b) had six twin-tube lighting fixtures T8 36W -Sylvania-, neutral light, 4300°K, heighted at 2.5 m above the workplane. The total and partial blockage of daylight allowed view and reference from outside. Both conditions had the same light uniformity and lighting levels between 100-300 lux of horizontal illuminance on the work-plane without sun patches or glare sources.

Result and Discussion

Our results, unlike those obtained in previous pilot studies (Ison and Pattini, 2009) showed no statistically significant relationship t (44) = 0.655, p > 0.05 (0.516) between attentional efficiency and the light However, source type. new evidence emerged from this experiment, and further studies are in development in order to find an expression that would relate the attentional effectiveness with a time factor. This way we would get more accurate results, letting us know not only the subject's production (effectiveness), but his ability to produce (efficiency) too. This metric would be more "sensitive" to the environmental conditions and to their influences on attentional skills.

Conclusions

The studies presented are framed within "the third stage" of lighting profession (Cuttle, 2011), dealing with the effects of lighting on basic psychological mechanisms, such as memory and attention. We addressed our investigation questions from a systemic perspective. analyzing the complex relationship between the subject, the task and the environment in terms of efficiency and effectiveness, as components of the overall performance of the task. The first steps were taken here. However, this perspective must be framed in a new paradigm: "healthy lighting", based not only on the photometric parameters of "good lighting", but on the effects of these on the subjects as well. These like others currently studies. under development by different laboratories, bring new proposals of methodological tools to evaluate lighting and its impact on cognitive aspects, such as memory working and attention, in order to provide light conditioning patterns that promote health and performance of the subject.

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HDR Images for Binocular Vision Evaluation in the Perception of Architectural Space: A First Approach

P. S. Scarazzato, D. F. Souza, & M. V. Dias

¹University of Campinas, School of Civil Engineering, Architecture and Urban Design, Campinas, Brazil

Introduction

Recent studies indicates that glare sources on a scene recorded in digital images can be easily detected, especially through the use of High Dynamic Range Imaging (HDRI) (VAN DEN WYMELENBERG *et al*, 2010). But current tools do not translate the human visual perception into something easily noticeable.

This poster presents a preliminary study, now in course at the University of Campinas, Brazil (Unicamp), that explores the possibilities of using HDRI as a qualitative indoor glare evaluation based on the human visual field.

Methodology

This study is divided into two parts: the capture and compilation of HDRI, and the preparation and analysis of visual field.

No special device or software was used, but only a SLR camera equipped with fisheye lenses and calibrated according to Jacobs (2007). A tripod and a computer remote control were used in order to stabilize the equipment and reduce the chance of errors in the HDR compiler.

After the compilation, the HDR image was opened in MATLAB. Using the basic library and the HDR Toolbox algorithms (BANTERLE *et al.* 2011), a routine was compiled to created a binocular visual field mask to superpose over the HDRI.

Evaluation and Discussion

The Fig. 1 shows one of the test shots, a workplace at the University. This HDRI shows that there are no major glare sources on the binocular field (e.g. the window is in the peripheral field).



Fig. 1: HDRI, gray scaled from 0 to 100 cd/m^2

Conclusion

This preliminary test shows that fisheye HDRI may be used to translate the human experience of contrast and glare perception. The superposition of the visual field made it easier to see the position of glare sources and to address its impact on vision.

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Application of the State-of-the-Art HDR Imaging Analysis in Lighting Research: A Pilot Study on King's College Antechapel, Cambridge

W. L. Lo, & K, Steemers

¹ University of Cambridge, Department of Architecture, Cambridge, United Kingdom

Pilot Study: King's College Antechapel

The perception of lighting is often complicated by an individual's role, eye movements and expectations. Its research progress is nevertheless hampered by heavy reliance on conventional physical light meters. In light of this, this paper presents preliminary findings of an ongoing research project, Cambridge King's College Antechapel Lighting Analysis, through the use of a state-of-the-art research tool, high dynamic range (HDR) imaging technique.

This pilot study examines lighting quality created by four artificial lighting scenarios, All Lighting, Rig Lighting, Interim Lighting and Proposed Lighting (single test unit only), with a critical analysis of their aesthetic appearance and lighting quality as perceived by audience members, conductor and musicians. The present Rig Lighting installed temporarily above the performance area of the Antechapel has received complaints about its low luminous intensity, uneven luminous distribution and visual distraction caused by the rig structure, raising the question of how a new lighting scheme, one that requires less energy consumption, might restore and maintain the sensible balance of lighting at the Antechapel.

HDR Photometric data analysis

Two approaches were set to analysis the HDR images of the Antechapel: I) To examine the luminance distribution based on non tone-mapped HDR images through the use of false-colour images and relative luminance maps; II) To examine the overall perceived brightness and contrast through mean (IM) and standard deviation (ISD) of RGB pixel intensity of tone-mapped HDR images.

Results and Discussion

False-colour images computed from the exact luminance levels do not indicate the way our visual system adapts to the threshold contrast between target and background luminances. A new way is therefore proposed to analyse the luminance pattern by mapping its relative luminance (RL). The RL is a ratio of spot luminance to maximum luminance of a visual field, and is defined as: RL = (Luminance_{spot}/ Luminance_{max}) x 100%. These maps reveal a rather surprising result concerning the brightness contrast of the Antechapel: despite giving the lowest average luminance, Proposed Lighting has the highest RL. With the ratio between the spot and maximum luminances considered. the silhouette and architectural details of the Antechapel can be seen in All Lighting and Proposed Lighting. Moreover, Interim Lighting proves to be moderately effective in revealing the complexity and impression of spaciousness of the Antechapel. Rig Lighting, however, fails to reveal any spatial details or to create any spatial or aesthetic impressions. Furthermore, the IM/ISD analysis indicates that the occupants may have better visual acuity under Proposed Lighting, and the perceived luminous is also likely to be more stimulating. These results suggest that the HDR imaging technique can provide richness of spatial and mathematical data to predict and evaluate visual perceived brightness appearance, and contrast of a complex context.

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"Day for Night" LED Digital Screens in Urban Public Spaces, any Risk for Occupants?

K. Talebian, & S. K. Kahouei

Eastern Mediterranean University, Famagusta, Cyprus

In many cultures around the world light brings such promising concepts as beauty, immortality and existence. The fascination of people to the light and in general to lit spaces had been used by powers throughout the history as an advantageous factor to boast their glory. Nowadays advertisement is also a tool for the powers to transfer their ideologies to public. Since currently replacement of static billboards with digital LEDs which can play thousands of commercial ads in an hours is getting common in big cities, this research seeks to find the possible effects of LED screens on occupants of a space regarding the popularity of this technology between advertisement industries.

As the brightness of Digital screens is much more than the former versions (statics screens), one of the primary effects of digital LED screens on the surrounding is the "Glare" effect. Figure 1 shows high contrast between new implanted LED screen in a roundabout in Famagusta, a developing city in Cyprus, and general lighting of the environment. Such condition may cause glare or even temporary blindness which is really unsafe especially for drivers. Another consequence of the new screen is disturbance in the hierarchy of urban illumination.



Fig. 1: LED screen extremely inharmonious with surroundings in Famagusta- Cyprus

The future of this phenomenon can easily be seen in developed cities such as Tokyo, where the high percentage of urban edges had been already transformed to large scale LED screens. (Fig-2) As can be seen from the figure above overall illuminations of urban edges are much brighter than the pathway. The over headed brightness of advertisement screens leaves the pathways dim and obviously causes unpleasant glare effect for pedestrians. Also researches by Fabio(2011), Behar-Cohen(2011) and Pode(2009) had shown the drawback of blue and white LED lights on circadian cycle of the body. By changes these lights make in melatonin



Fig. 2: General illumination of a public urban space in Tokyo – Japan

production of the brain such diseases as insomnia, high stress level and even cancer may emerge depending on the length and intensity of radiation.

This survey pointed out three negative effects of LED screens; 1-Glare 2-Harmony disturbtion 3-Circadian cycle disorder. Further researches are essential to examine other possible effects of LED screens in order to survey the necessity of controlling guidelines for these products.

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A Three Step Method to Design Lighting in Hotel Rooms Through a User Centered Approach

P. Fernandez^{1,2}, A. Giboreau², & M. Fontoynont³

¹ Université Lyon 1, Lyon, France ² Research Center of Institut Paul Bocuse, Ecully, France ³ Danish Building Research Institute, Aalborg University, Denmark

Introduction

The quality of light depends on photometric parameters such as quantity (Boyce, 2003; Cuttle, 2004), colour temperature (Knez, 1995), and spatial distribution of light (Durak, Camgöz Olguntürk, Yener, Güvenç, & GürçInar, 2007). It also depends on the user perceiving the luminous environment (Knez & Kers, 2000; Rikard Küller, 1986) and the use of the luminous environment (Butler & Biner, 1987: Nakamura & Karasawa. 1999). Methodologies of past studies instructed people to give their environment appraisal by imagining being in an empty room (Van Erp, 2008) or a furnished room (Nakamura & Karasawa, 1999), using a reduced scale model (Oi, Kasao, & Takahashi, 2007), or in a real situation (Oi, et al., 2007; Tabuchi, 1985). However, most of the studies focused on light perception have been conducted in laboratory settings. Even if some of these studies involve highly elaborated experimental design, it was felt appropriate to consider visual factors simultaneously under realistic conditions (R. Küller, Ballal, Laike, Mikellides, & Tonello, 2006).

Moreover, very few studies investigate the relation between lighting and individual preference in hotel, although hotels managers and architects are starting to recognize the importance of hotel design both from an architectural and an interior design perspective (Countryman, 2001; Siguaw & Enz, 1999).

This study also aims to better understand the perception of lighting in hotel rooms from a user's perspective. The design of a luminous environment must consider different parameters for creating an environment that matches the expectations and needs of the user (Boyce, 2003). The study is also designed in three steps in order to highlight light perception based on a user centered approach.

Methodology and Main Results

The originality of this work lies in the "waterfall" approach, since each phase in the study uses the results obtained in the previous stage. A classic analytical approach of psychophysics aims at evaluating the influence of a parameter on individual behaviour. Instead, we based preference on a global approach, which takes the environment as a whole where individuals interact.

The first phase of our study aimed at understanding how a customer in a hotel room experiences the light. In other words, it was to clarify how and when the lighting was influencing the customer's experience. To this aim, a qualitative approach was conducted through individual interviews (30 to 45 minute each). Eighteen customers (66% male, N=14 business) were interviewed in two different hotels (3* and 4*). The interview started with general observations which led to the identification of the customer's conception of comfort in hotel. Then questions focused on the role of lighting and also daylighting in the general assessment of the spaces.

As an example, the quotation bellow illustrated the results that we obtained:

"Well, for me, comfort is to have the right temperature, the right lighting, light and noise" UG25

Discourse analysis was done through each individual corpus in order to identify the



Fig. 1: Example of one tested set: color temperature of the light

relevant elements. Those parameters retained as relevant are: interaction with natural light, the quality of light, and the convenience facilities. The perception is also influenced by the user's activity. Six basic use situations were found: arrival in the hotel room, leisure time, working time, sleeplessness, the situation switch on and the situation switch off. It also appears essential to be able to personalize lighting depending on the use in the different main situations in a hotel room.

The second phase of this work consisted in identifying the lighting parameters that influence an individual's evaluation. Thirty nine images representing the same hotel room were rendered in 2D (V-Ray rendering engine) and grouped into several sets. Each set was the declination of a luminous parameter in three or four modalities. The images were produced in relation to typical situations which were identified in the previous step (Figure 1).

The experimental device was set in a real hotel lobby 103 customers (60 % business, 67% male) were asked to choose the most preferred and the least preferred luminous environment using a computerized questionnaire.

On one hand, this approach allowed for the identification of relevant parameters contributing to the appreciation of a hotel room, regarding esthetical parameters (shape and colour of luminaires) and photometrical parameters (quantity and orientation of the luminous flux). For example, the figure below shows the preference for lighting condition with different color temperatures (CCT).

Statistical analyses (Friedman test) showed that colour temperature of light influenced the appreciation of the environment. The colder light was less appreciated than the warmer (mean \pm SD: 4200° K=1.79 \pm 1.1; 2700° K=2.78 \pm 0.8;



Fig. 2: Influence of the colour temperature of light from a wall--mounted lamp on preference of lighting scenarios. Friedmann test, mean rankings characterised by the same letter are not a significantly different risk ($\alpha = 0.01$)

 3000° K=1.13 ±2.9; 3700° K=2.56 ±0.8) (Figure 2).

On the other hand, this step revealed different preferences of lighting conditions according to the situation, which was then evaluated (data not shown). Lighting conditions were different in terms of quantity and colour temperature. Hence, those results led to an operational selection when designing the experimental device in real situation.

The third phase investigated the contribution of illuminance and colour temperature (CCT) to the user's room assessment in a real hotel room. More specifically, this step aimed at better understanding how the user's activities influence his/her perception of the lighting condition in a hotel room.

The study involved 203 customers (53% male) in a hotel room specifically equipped to implement the testing (3*hotel). They were asked to evaluate the same four lighting conditions during three different activities: watching a movie, typing a text on a computer, and looking at him/herself in a bathroom mirror. These activities are respectively named situation of leisure, situation of work, and situation in the bathroom. Two parameters were considered: illuminance (30% (Dim); 100% (Bright) of luminous flux) and CCT (Warm White (WW): 2700 °K; Cool White (CW): 4200 °K).

After seeing the four conditions for each situation, users had to assess the lighting



Fig. 3: Picture of the lighting conditions. A.Dim WW; B: Bright WW; C: Dim CW; D: Bright CW

conditions on a visual analytical scale. As an example for the working time, the question was: *When you are working, do you like this atmosphere?*

In the situation of leisure, users preferred the warmer and dimmer condition (Dim WW) and discarded the colder and brighter condition (Bright CW).

In the situation of work, users preferred the warmer and brighter condition (Bright



Fig 4: Mean scores of appreciation of lighting conditions Dim WW, Bright WW, Dim CW and Bright CW for a situation of leisure. Mean scores identified by the same letter are not significantly different (ANOVA, $\alpha < 0.01$).



Fig. 5: Mean scores of appreciation of lighting conditions Dim WW, Bright WW, Dim CW and Bright CW for a situation of work. Mean scores identified by the same letter are not significantly different (ANOVA, $\alpha < 0.01$).



Fig 6: Mean scores of appreciation of lighting conditions Dim WW, Bright WW, Dim CW and Bright CW for a situation in the bathroom. Mean scores identified by the same letter are not significantly different (ANOVA, $\alpha < 0.01$).

WW) and discarded the other conditions (Dim WW, Dim CW, Bright CW).

In summary, statistical analysis revealed significant differences between lighting condition preferences, according to the activity experienced. In the situation of leisure, people preferred a subdued atmosphere. In other situations (when the user is working or looking at him/herself in a mirror), people expressed a preference for the brighter lighting, that provided more visual comfort.

Academic and operational benefits of the study

This study contributes to a better knowledge of the construction of the perceptive experience of humans in their From an academic point of view, this study shows the influence of the user's situation on lighting preference. Moreover, this study brings a methodological contribution to the study of the perception of a physical environment by its users. This study introduces a three-step approach to reach a better understanding of the interaction of humans with their physical environment.

From an operational point of view, the aim of this study is an optimization model of perceived quality in hospitality that would take into account cognitive processes in situation as well as light characteristics: quantity and colour of lighting interacting with design elements, furniture, accessories, materials, etc.

As a perspective, the validation of the perceived quality model could also include

the evaluation of its solidity in new situations with entry keys of new uses according to the kind of establishment and/or customers.

In other words, this study's results are directly applicable to hospitality specialists, engineers and lighting designers by means of inducing a simplification of the conception process for future comfortable luminous environments in a similar context.

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User-based Research Approach for Assessment of Non Visual Lighting Effects

B. T. Martau¹, M. P. Hidalgo¹, C. Luz², F. Kubaski¹, & F. H. Corrêa¹

¹ Federal University of Rio Grande do Sul, Porto Alegre, Brazil ² LabVitrus, Porto Alegre, Brazil

Introduction

The need for understanding users' desires and the way they live and work in architectural spaces generated the need to also understand the human physiology to design. Biological rhythms such as restactivity rhythm, social rhythm, body temperature rhythm and hormonal levels (melatonin and cortisol) can be easily measured and they are related to lighting. The role of lighting, especially artificial lighting, and its relationship with biological processes, is fundamental to define new guidelines project and assess the consequences of the specifications of different lighting environments.

Methodology

The general goal of the study was to evaluate how lighting conditions interfere in the health and well-being of employees from shopping malls and hospital building. The sample consisted of 50 woman aged between 18 - 65 years old. They were divided in five groups of ten subjects: with presence of day light and daytime work (one group in mall (A) and other in hospital (E)) and without presence of day light, and daytime working hours (one group in mall (B) and other in hospital (D)), and a group without presence of day light, and afternoon and evening working hours (2 p.m. to 10 p.m.) in shopping mall retail spaces (group C).

Visual, biological and emotional aspects were correlated with the lighting system variables. The methodology used instruments from psychological and medical areas. The procedures included evaluation of lighting conditions and illuminance and the subject's light pattern (using a luxmeter in the wrist called actigraph).

Results and discussion

Having visual contact with the outside throughout windows was an important factor for groups A and D to present better well being indicators in the assessment. Results indicate direct and indirect correlations between this factor and higher depression and anxiety scores in groups without natural light (B, C and E). The subjects of group B and D showed the worst conditions in the assessment of anxiety and stress (cortisol levels) among the five groups, probably because they had no contact with natural light. In group C, where average general illuminances were up to 700 lux, physiological alterations where found in melatonin production and the worse condition in the assessment of depression. Results showed that the circadian rhythms indicators are important and new methodologies could include then as an innovative design tool for lighting designers.

This knowledge might be used to develop ways of intervening in the health-disease process, composing a set of guidelines that can be included in rules and regulations for the production of architectural spaces.

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M-Beam: A Tangible Atmosphere Creation Interface

J. Westerhoff¹, R. van de Sluis², J. Mason², & D. Aliakseyeu²

¹ Westerhoff Ontwerp, Tokyo, Japan ² Philips Research, Eindhoven, The Netherlands

Introduction

The advances in Light Emitting Diode (LED) technology have caused a profound change within the lighting industry. This is in part due to the LED's key properties of being physically small, highly efficient, digitally controllable and soon, very cheap to manufacture. With the highly adjustable characteristics of LED lighting the function lighting goes beyond functional of illumination. One of the areas where the richness of LED lighting has the potential to change our design freedom radically is in lighting atmosphere creation.

In this paper we define atmosphere as the observable affective state of an environment. In other words, you can observe that a room's atmosphere may be associated with a certain feeling such as being happy or romantic, without having to feel that way complex yourself. The thing about atmospheres is that anything in the room can influence it. These things can be deliberately chosen by people, such as with the wall colour or playing music. However, there are also uncontrollable factors like the weather outside or the mood of the people inside the room. It is the combination of all these influences that determine what kind of atmosphere a room may be perceived as having. Some influences are more dominant than others, for example a room can be beautifully illuminated by the morning sun, but the mood of atmosphere may be perceived as being very tense if there is also a serious business meeting taking place.

The focus of our research was on influencing atmospheres to try and create a particular mood. The two main influencing factors used were light and music. Depending on the desired (selected) mood for a room's atmosphere the light and music would then be altered to provide an output that would potentially influence the atmosphere so that it would be perceived as having the selected mood. Moods can be expressed in many different ways; we were interested in exploring how the mood can be expressed in the physical interface both in the form of the user interface (UI) as well as in the interaction with it so to facilitate the selection of moods for an atmosphere.



Fig. 1: M-Beam: UI concept to control atmosphere

In this paper we present a UI concept resulting from this exploration named the "M-Beam" (see Figure 1). M-Beam is a user interface for controlling certain atmosphere influencing factors. It was designed with the intention to provide optimal freedom of mood expression (for the intended atmosphere) as well as to communicate clearly the current state of the system (mood) to users.

Related Work

Lighting based atmospheres and atmosphere controls

Several examples of influencing an atmosphere with colored lighting are described in the literature. There is also a number of existing products that support lighting based atmosphere creation. A notable example is the Philips Living Colors luminaire. It provides people with a simple way of adding colored light into their homes so to create different atmosphere moods using light.

Another example is the Citizen-M hotel that offers a selection of different lighting based atmosphere moods for their guests. When guests check in online they can select from a range of atmosphere moods and when they arrive at the hotel the room automatically sets itself up to try and provide this. For controlling the mood of the atmosphere it uses a preset approach where every preset is described by an icon and a keyword such as 'romantic'.

Expressive UI

Expressive or emotional UIs are known in the literature. A notable example is an alarm clock created by Stephan Wensveen (2002). The sliders on the side of the clock set the alarm time, and multiple combinations of the sliders can reach the same result. The pattern of the sliders tells the system something about the mood of the user: a messy pattern could mean the user is stressed, while a nice even pattern could mean 'relaxed' (Wensveen et al., 2002). Carousel (Ross and Keyson, 2007) is another example of an expressive UI that combines atmosphere creation with expressive tangible interaction. It consists of an object with several possibilities for interaction. The 'flags' on the top of the device can be arranged in different patterns, showing an 'open' or 'closed' position.

We see the mood-setting as a central part of the UI, expressed through the physical state of the interface. The essence of the interface design is that physical state of the interface should reflect the overall mood. The projects by Wensveen and Ross also touched upon this idea with their 'traces' of interaction. We take this link between mood and the physical appearance of the interface as the most important interaction with the UI with a goal to make the interaction with and appearance of the UI as a part of the total atmosphere. The rest of the paper is structured as follows: firstly we describe the results of the user investigation that was aimed at understanding how people create atmospheres in their homes. Secondly we present the design and the implementation of the M-Beam prototype, and we finish with the user evaluation of the prototype.

User Investigation

People's perception, method of creating and underlying need for having different atmospheres in the home varies greatly depending on their age, culture, social status and other factors. For this reason we decided to focus our attention on one specific group of people.

Socially active young adults (Dutch, age 25 - 32) were chosen as a target group for the M-Beam concept. The choice was driven by the assumption that people from this group already have ample experience with different forms of multi-modal atmospheres in clubs, bars and other public places. Consequently, they might be more open to the creation of similar experiences in their home environment.

A set of contextual inquiries was conducted to investigate how people from this target group currently create atmospheres in their homes, and what products they use to do it. The contextual inquiries were performed in the participants' homes, and the participants were asked to use their own products during the inquiry. They were asked to create two different atmospheres in their living rooms: one for a 'party' and another for a 'romantic' night in. They could use whatever they wanted to create these During the creation of the atmospheres. atmospheres the participants had to talk about all of the steps they were taking, and how it contributed to the atmosphere. Six participants were visited in total (average age: 27, 2 females).

The researchers created detailed descriptions of the living rooms of the participants and the items they used to create the atmospheres. Participants were interviewed afterwards.

 Table 1: Moods and associated keywords

Нарру	Calm	Sad
up	stability	closed
festive	smoothness	enclosed
upward spiral	grounded	low
open posture	wideness	heavy
release	slow-down	pointing downwards
open	natural colours	narrow
-	inatarar voroaro	limited perspective

One of the main findings from the study that all participants started the was atmosphere creation process by adjusting the lighting. They either dimmed the lights, or added colour or other small lamps. As a second step all of the participants adjusted the music, both genre and volume. Other factors that were of influence to the atmosphere were location and accessories. The location in the room was interesting, because participants showed a strong preference for specific locations in which they wanted to create the atmosphere. These locations were very personal and different for most of the participants. For example, 'romantic' meant sitting on the couch for one of the participants while it meant sitting at the dinner-table for the other. The use of accessories was also interesting, but seemed to be very personal. One participant used scented oil to set the mood, but she also expressed that the same scent could be used to support different moods.

The main conclusion was that music and light were the two main factors selected for influencing a room's atmosphere. Moreover music and light not only affect the atmosphere, they are also easily manipulated. In contrast, the furniture arrangements for instance also contribute to the atmosphere, but remain mostly constant.

The results of the inquiry were used as a starting point for the designing of the M-Beam system that is described in more detail in the next section.

Design

The design was distilled from several cocreation sessions. After each session a short user-evaluation was held to select the best ideas. With these winning ideas another cocreation session was held to elaborate on these ideas. All the sessions were organized using physical sketching techniques so that interactions could immediately be felt and shown. We believe that this physical approach to brainstorming was the best method to experience immediately the interactions that the participants came up with.

Linking mood with physical stance of the interface

One of the important goals of the M-Beam design process was to be able to represent moods by the physical stance of the interface. Tinkering and card sorting methods were used to identify the links between stances and moods.

Tinkering is a brainstorm like session where the participants suggest ideas in a physical form rather than written or sketched. The tinkering sessions were done with a group of volunteers from the office at Philips Research. The participants were asked to build physical interactive objects using tinkering materials. The task was to create objects that could express a specific mood by the way they moved and looked physically. After several tinkering rounds the group was asked to build a final object that could express the whole range of moods. All the tinkering objects were kept for later use as inspiration for the design phase and a group discussion was held so the participants could describe and explain their objects. These explanations were video recorded to ensure the participants responses were not lost or misinterpreted later in the design process. After this the researchers made a series of cards with pictures of the three main concepts from the tinkering sessions. Each series of cards (three series) consisted of a range of physical stances of the objects. The researchers asked six participants to arrange the cards from a 'sad' mood to a 'happy' mood.

The tinkering and card-sorting sessions gave clear directions for the design of the physical interface. During the sessions several keywords were determined by the group that best described the concepts. Table 1 shows which keywords were allocated to which mood. The used keywords show that angle as in physical orientation (up, pointing downwards, upwards spiral) appears to be a



Fig. 2: Setting mood by manipulating the M-Beam.

clear common parameter. Another parameter that was apparent in several ideas from these sessions was the openness of the object. Closed objects represented strongly a sad mood, while open objects suggested happiness.

M-Beam prototype

The prototype consisted out of a physical interface (see Figure 2) and a 'behind the scenes' controller for music and light. The system used an approach described by Skowronek et al. (2006) to determine the mood of any given song, and to categorize it. Attached to these mood categories are light settings that vary the hue, saturation and amount of coloured light. When the user selected a mood using the interface, the system would automatically choose the most fitting music and light-settings.

The user interface itself is a light-emitting object that co-exists with the atmosphere creation system. Its form is a round angular shape with an aperture that emits light (see Figures 1 and 2). By placing the M-Beam on one of its angled sides, the angle of the lightbeam is changed giving the overall object a different expression. The aperture can be adjusted as well, to give the beam of light a different width. The light emitting from the object remains constant, only the angle and width can be changed. Combining the angle of the beam with its width allows the user to express different moods for the system to create, where angle is associated with sad and happy or valence and beam width with low or high energy or arousal. In this respect the system uses two dimensional Russell's circumplex model of affect (Russell, 1980).

The system interprets the user's input and selects the appropriate songs and lightsettings. The physical appearance of the interface changes when the user is interacting with it. It changes in such a way that it expresses the mood of the atmosphere that is being created, and by doing so it stays in harmony with the atmosphere. The interface expresses the overall intended mood of the atmosphere, and fits in with both the lightsettings and the music in the room.

The concept is best described with an example, seen from the user's perspective. When a user wants to create a 'happy' mood, they use the interface to activate it. To express happiness the user can adjust the angle of the light-beam so that it points upwards to the ceiling, and to accentuate a high-energy happiness the width of the beam can be widened.

The system interprets these two settings as being a 'happy' expression and selects an appropriate song and light-setting. The user has now experienced the creation of an atmosphere in which the interaction with and the physical appearance of the interface are in harmony with the resulting atmosphere. The interface is designed to keep on fitting in with the atmosphere that is being created by the user, even after the interaction has ended.

Conclusion

In this paper we presented the M-Beam – a physical interface for controlling atmospheres using mood as a way to define what combination of music and coloured light should be used to create the atmosphere. The M-Beam is an example of an expressive UI for its appearance and operation directly relates to the desired mood setting.

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The Perception of Brightness at Conservation Light levels in Museum Environments

M. Innes

Edinburgh Napier University, Edinburgh, Scotland

Introduction

Despite continued improvements in the quality of LED sources, tungsten halogen is still the dominant light source in museums and galleries around the world. The \$74m refurbishment of the National Museums of Scotland (completed 2011) uses over 1,000 low voltage TH spotlights to illuminate the dim, exhibits. The warm glow of conservation lighting remains the norm. However, as energy legislation is tightened and LED technology becomes more affordable, LED luminaires will become standard. Should/could these LEDs emulate TH sources? For museums that adopt LED, what is the best colour temperature for low light conservation galleries?

The author's empirical experience from 20 years of lighting conservation galleries is that TH sources with a higher colour temperature enhance the perceived brightness of exhibits. Could this empirical evidence be replicated experimentally and could it be used to identify the best colour temperature for LED sources in low light galleries?

An Experimental Gallery

A faux exhibit was set up with two identical monochrome prints side by side. A dimmed 50w low voltage TH source illuminated the left hand 'target' print. The right hand print was illuminated by a user dimmable 20w TH, (producing a relatively cooler light for equal illuminance). After a period of adaption, 22 subjects viewed both prints and adjust the 20W source to match the 'brightness' of the left hand 'target' print. This task was carried out with nominal target illuminance of 50lux and 100lux (presentation order was randomised).

The tests were then repeated with high quality remote phosphor LED spotlights.

Results

For the nominal 50lux tests, 21 of 22 subjects set the cooler light source to a lower illuminance to achieve an 'equal brightness'. The mean illuminance of all 22 results was 22% lower than the target source. For the nominal 100lux tests, all 22 subjects set the cooler source to a lower illuminance with a mean illuminance 31% lower than the target source.

Although it was expected that this effect would be replicated with warm and cool LED sources, the tests with dimmable 3,000K and 4,000K LED sources had no consistent pattern and displayed no correlation with the TH results. Furthermore, many test subjects reported having great difficulty in brightness matching the two LED sources.

Conclusions

For museums and galleries using TH, illuminance can be reduced, or perceived brightness of sensitive exhibits can be enhanced, using the cooler light of low wattage less dimmed TH sources.

LEDs sources cannot be considered as simple like-for-like replacements for TH in conservation lighting. Further work is required is required to determine the most effective colour LED temperature range and spectral power distribution to enhance brightness perception in low light galleries.

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Further information

For graphs showing results and further information contact: <u>m.innes@napier.ac.uk</u> or visit: www.lightartist.info/brightness.

Blind Control Method Based on Prevention of Discomfort Glare Taking Account of Building Conditions

T. Taniguchi¹, T. Iwata², & D. Ito³

¹ Graduate School of Tokai University, Hiratsuka, Japan,
 ² Tokai University, Hiratsuka, Japan
 ³ Institute of Technologists, Gyoda-city, Japan

Introduction

For Energy-saving by using daylight, automated control systems of venetian blinds which are admissible for the Comprehensive Assessment System for Built Environment Efficiency (CASBEE, 2010) point system, have been widely used in office buildings in Japan. Since the sun-cut position of the slats is insufficient to prevent discomfort glare, automated control based on discomfort glare prediction has been proposed (Iwata et al, 2011). This paper shows a blind control algorithm taking account of building conditions, e.g. surrounding buildings and eaves, which have significant effects on discomfort glare from daylight.

Flow chart of a blind control based on discomfort glare

Figure 1 shows the flow chart of controlling blind based on discomform glare. The details are explained in the following.

Control method of slat angle

The sun-cut angle is calculated from the profile angle (see Figure 2, Equation 1 and Equation 2). The existing blind control method to avoid discomfort glare, off-set angle (see Figure 2) is added to the sun-cut angle until discomfort glare is accepted by observers as shown in Figure 1.



is part added to the original flow chart (Iwata et al, 2011)



Fig. 2: Sun-cut angle and off-set angle

$$Ap = \frac{\tan h}{\cos(A - Av)}$$
(Eq.1)

$$\theta_{sun-cut} = \frac{\frac{2}{w}\cos Ap}{\sqrt{1 - \left(\frac{s}{w}\cos Ap\right)^2}} - Ap$$
(Eq.2)

where Ap is profile angle [deg], h is Solar altitude [deg], (A - Av) is Solar azimuth to the window plane [deg], S is slat distance [mm], W is slat width [mm] and $\theta_{sun-cut}$ is sun-cut angle [deg].

Component of façade luminance

PGSV requires the average luminance of the window calculated. Average luminance of the windows is composed of the blind slat and the sky which can be seen between the blind slats and is calculated by Equation 3.

$$Lw = \frac{L_b\omega_b + L_{sky}\omega_{sky}}{\omega_b + \omega_{sky}}$$
(Eq.3)

Where L_b is luminance of blind slats [cd/m²], L_{sky} is luminance of sky [cd/m²], ω_b is solid angle of blind slats [sr] and ω_{sky} is solid angle of sky [sr].

However, in actual conditions, the window has surrounding objects (buildings, trees or eaves) which are seen between the slats and prevent direct sunlight from hitting the blind slats partially. This study takes account of surrounding objects and their effects on the average luminance of the windows is calculated with the following equation (Eq.4).

$$L_{W} = \frac{\sum L_{i}\omega_{i}}{\sum \omega_{i}}$$
(Eq.4)

Where L_i is luminance [cd/m²], ω_i is solid angle [sr], subscript *i* substitutes parts e.g. blind slats hit by direct sunlight, blind slats without sunlight, sky seen through the slats, surrounding objects (buildings or trees)seen through the slats.

Slats luminance

The luminances of the blind slats are calculated from the outside illuminance in the following equation (Eq.5) (Shukuya, 1993).

$$\left(\frac{L_{1}\pi}{L_{2}\pi}\right) = \begin{pmatrix} \rho_{1}^{-1} & -F_{12} \\ -F_{21} & \rho_{2}^{-1} \end{pmatrix}^{-1} \begin{pmatrix} M_{1} \\ M_{2} \end{pmatrix}$$
(Eq.5)

Where L_1, L_2 : luminance downward slat saurface1 and from upward slat surface 2 [lm/m²], M_1, M_2 : illuminance of downward slat saurface1 and upward slat surface 2 provided by direct sunlight, sky light and light reflected on the ground [lx], ρ_1 , ρ_2 : reflectance of downward slat saurface1 and from upward slat surface 2[-] and F_{ij} : form factor from area *i* to area *j*[-].

PGSV (Predicted Glare Sensation Vote)

PGSV which predicts discomfort glare from daylight was proposed (Iwata et al, 2008). PGSV is calculated in the following equation (Eq.6).

$$PGSV = \log \frac{L_s^{3.2} \omega^{-0.64}}{L_b^{0.61-0.79 \log \omega}} - 8.2 \quad \text{(Eq.6)}$$

Where L_s is luminance of light source [cd/m²], L_b is luminance of back [cd/m²] and ω is solid angle of light source [sr].

Calculation result of average luminance of the window

Global illuminance and sky illuminance were measured on the roof for 3 days (December 12, 13 and 15 in 2011). In the conditions shown in Table 1, the average luminances of the window were calculated by the method of this study which takes account of the surrounding objects and the method of previous study which had no surrounding objects. Figure 3 shows the calculated value of average luminance of window and cut-off angle on December 13. The average of luminance of the window calculated by the method presented in this paper is about a half of that's presented in the previous study. PGSV shows 0.5 to 1 of these differences.

]	35°21′39″		
L	139°16′34″		
Faça	2°30′00″		
Surround	Distance,	20m	
objects	Height	8m	
Earra	Length,	0,6m	
Lave	Height	2,7m	
Reflectance	Eave back,	0.1	
	surround object	0.2	
Dlind alot	Slat width,	35 mm	
	slat distance	30 mm	
Dilliu siat	Reflectance	0.74	
	saurface1,2	0.74	





Subjective experiment

In the previous study, since the ratio of the slat luminance to the sky luminance seen between the blind slats was 0.2 to 1, the whole windows were considered as a glare source (Iwata et al, 2011). However, the calculation method in this study makes the unevenness of luminance distribution within a window larger. The effect of unevenness of luminance distribution on discomfort glare is tested in this experiment. The subjective experiment was carried out by using actual window with automated blind. The experiment was carried out on December 12, 13 and 15 in 2011.

Methods

To keep 500 lx to 1500 lx of desk illuminance, a partition was used on the desk. Experimental conditions are shown in Table 2. Slat angle is determined to keep sun-cut angle calculated with Eq.2. ND filter was used to make mock shadow of eaves so that a constant length of the shadow can be obtained (see Fig. 4). The transmittance of the ND filter was 25 %. In total, 6 conditions

(3 lengths of eave shadow \times 2 distances from the window) were tested. Figure 5 shows the test room. The width of the window is 5400 mm.

Table 2Experimental conditions							
Slat angle	Length of	Distance from the	Solid angle of				
	shadow	window	the window				
Cut-off angle	0 mm 400 mm	1.5 m (0.65) 3.0 m (0.29)					
ungre	850 mm						



Fig. 4: Setting ND filter



Subjects entered the test room and took a seat each. Simple task was carried out on the desk for one minute. After that, the subjects were asked to evaluate glare at the window. Subjects evaluated by Glare sensation vote (just perceptible=0, just noticeable=1, just uncomfortable=2, or just intolerable=3). Glare evaluation was achieved by 3 subjects in one group. Eighteen students participated as subjects (average age 22.2). Each subject evaluates all conditions every one hour.

Results

(1) Luminance distribution of the window

The images of luminance distribution were taken for subjective experiment. Figure 6, 7 shows the images of luminance distribution of the window in the case of 1.5m distance from the window in December 13. Global illuminance was about 60300 lx, sky illuminance was about 10500 lx at noon.



Fig. 6: the images of Fig. 7: the images of Continuation for an images of Fig. 7: the images of Continuation for an images of Fig. 7: the images of Continuation for an image of the images of Fig. 7: the images of Continuation for an image of the image

(2) Comparison with PGSV to subjective evaluation

Figure 8 shows PGSV and subjective evaluation in the case of 0 mm of the eave shadow. subjective evaluations are closer to PGSV taking account of surrounding objects than to PGSV without surrounding objects. The median and 25% and 75% tile value were used to indicate subjective evaluation. PGSV calculated by the method presented in this study could predict glare sensation in the morning, while it overestimated in the afternoon. When the off-set angle is determined to keep the glare accepted by 80% of workers (1.2 of PGSV), 0 degree of off-set angle is required in this condition.



Fig, 8: Comparison of the predicted PGSV with evaluated value (the eave shadow is 0 m, December 13, 2011)

(3) *Effect of the eave shadow and distance from the window*

ANOVA was carried out and a significant effect of eave length on subjective evaluation was found. Figure 9 shows PGSV and subjective evaluation for each length of the eave shadow in the case of 1.5 m distance from the window. In 1.5 m distance from the window, a significant difference of subjective evaluation was between 400 mm and 850mm of the length of the eave shadow (5 % of the significant levels). For both subjective evaluation and PGSV, no significant difference was found between 0 mm and 400 mm. Figure 10 shows that of 3.0 m distance from the window. In 3.0 m distance from the window, the PGSV of this study was lower than subjective evaluation.



The blind control method preventing discomfort glare which takes account of surrounding objects is proposed. The shadow of the surrounding objects reduces the luminance of the part of slats and consequently reduces the average luminance and PGSV. The result of the subjective experiment showed a significant effect of the shadow of the surrounding objects on glare sensation. This method can reduce the off-set angle (additional slat angle) and encourage use of daylight.

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Always Look on the Bright Side of Life: Ego-Replenishing Effects of Daylight versus Artificial Light

F. Beute, & Y. A.W. de Kort

Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

Vitality is an important indicator of wellbeing and feeling vital is something we often strive to achieve. Vitality not only entails feeling energetic but is also about experiencing positive affect. In other words, subjective vitality concerns the amount of positive energy you experience (Nix, Ryan, Manly & Deci, 1999). Vitality is influenced by both somatic and psychological processes and has been linked to both mental and physical health (Ryan & Deci, 2008). When people feel vital they are better able to cope with stress, or even viruses (Ryan & Deci, 2008). Moreover, it has also been suggested that people who feel vital are more able to self-regulate (Muraven, Gagné and Rosman, 2008; Ryan & Deci, 2008).

The world around us is full of temptations. To resist these temptations, we need selfcontrol. Self-control, or self-regulation, is also needed to control attention or impulses, guide behaviors, decisions, and thoughts for instance to achieve long-term goals, or to act in a socially desirable way. Ego-depletion Theory (Baumeister, et al., 1998) suggests exerting self-control temporarily that depletes a common resource, a process ego-depletion, resulting labeled in a temporary decrease in capacity to exert selfcontrol. Earlier research has indicated some ways to overcome ego-depletion as consuming glucose, positive affect and autonomy (see: Hagger, Wood, Stiff & Chatzisarantis, 2010). These three ways to restore depleted resources are all related to vitality, either by directly increasing vitality (autonomy, see Ryan & Deci, 2000) or by increasing energy (glucose) or positive affect. Indeed, it has been found that vitality mediates ego-depletion (Muraven et al., 2008). Thus, finding ways to increase vitality might help us deal better with temptations

and help us achieve long-term goals. In the present research we focused on how light daylight in particular - can help restore selfregulation capacity.

Exposure to light might also be a good candidate for ego-replenishment. First of all, exposure to bright artificial light has been found to directly increase vitality (Partonen & Lönnqvist, 2000) and increase mood (Kaida, Takahashi & Otsuka, 2007). The opposite phenomenon, a lack of exposure to daylight, can cause symptoms of Seasonal Affective Disorder (Rosenthal, et al., 1984). Therefore, we expect exposure to bright light can help overcome depleted resources.

We further expect that natural light exposure will have an additional replenishing effect compared to artificial light exposure. People generally believe that exposure to daylight is beneficial for many aspects of wellbeing, such as health, mood and performance (Veitch & Gifford, 1993). People also prefer environments that are sunny and bright (Beute & de Kort, under review). In turn, preference for environments has been found related to the replenishing potential of these environments (Van den Berg, Koole & van der Wulp, 2003). In a different line of research, it has been found that humans can recover from stress and resource depletion in natural environments as opposed to the more artificial urban environments - effects often attributed to evolutionary adaptation and information processing (Kaplan, 1995 & Ulrich, Simons, Losito, Fiorito, Miles & Zelson, 1991). Furthermore, studies have shown that natural environments can increase vitality (Ryan, Weinstein, Bernstein, Brown, Mistretta & Gagné, 2009) as well as help replenish diminished self-regulatory resources (Beute & de Kort, in preparation). Thus, we expect that the naturalness of daylight will cause an increase in recovery as compared to artificial light through affective and evolutionary processes, and due to beliefs about daylight and preferences for daylight.

In the present study we will therefore investigate whether light can help overcome ego-depletion. We will compare the replenishing effectiveness of daylight with that of artificial light matched in brightness. Data-collection and analyses for this study are still ongoing, but are planned to finish in June.

Method

This study consists of four conditions. The first condition was a control condition without ego-depletion and light exposure (non-depletion no-light condition). The other three conditions were all with ego-depletion followed by respectively no light change (depletion no-light condition), or exposure to daylight (depletion daylight condition) or artificial light (depletion artificial light condition).

Participants

We plan to run eighty participants in total. At present, sixty-two participants have already participated.

Setting

Ceiling luminaires provided basic lighting throughout the whole experiment. The lighting level was 200 lux at 4000 K measured at eye-level.

Ego-depletion Manipulation – Typing task

Participants had to blindly retype a paragraph. In the non-depleting condition no restrictions were given. In the depleting conditions, participants were instructed not to type the spacebar, 'e', or 'p' and the number of errors made was displayed on the screen.

Light Manipulations

No-light condition: In the no-light condition, no additional light was added after the ego-depletion induction.

Daylight condition: In the daylight condition, daylight was allowed to enter the room after the ego-depletion induction by opening an automatic sunblind. A translucent foil on the window prevented a view to the outside. The sunblind remained open until the end of the experiment. Illuminance was measured continuously using two lux-meters (Hagner detector SD) placed on the desk and at eye-level. After the experiment, colour temperature was measured using a jeti spectro-radio meter (specbos 1201).

Artificial light condition: In the artificial light condition, lighting conditions were matched in average light intensity and colour temperature to the daylight condition with an additional wall-mounted luminaire, which remained on until the end of the experiment. Intensity and colour temperature were matched to the daylight conditions.

Measures

Psycho-physiological measures. During the experiment, heart rate and heart rate variability were measured continuously with a sampling rate of 2048 Hz. For the heart rate measures, electrodes were placed according to the lead-II placement using Kendall Arbo H124SG elecrodes.

Mood was assessed three times in the nolight conditions (at baseline, after the typing task, and after the dependent tasks, see below) and two times in the daylight and artificial light conditions (at baseline and after the dependent tasks). Four dimensions of mood were included: sadness, positive affect, energy, and tension. Participants were asked to indicate their feelings at that moment on five-point scales (not at all, a little, moderately, quite a bit, extremely).

Stroop Task. During the Stroop task, the words 'red' and 'blue' were displayed on the screen with red or blue font colours. Participants were asked to indicate the font colour. In congruent trials the font colour and word were similar, in incongruent trials the font colour and word differed. This task requires inhibition of the written text. The baseline Stroop task consisted of 80 trials (16 incongruent) and the dependent Stroop task consisted of 200 trials (40 incongruent). Dependent variables were reaction times on incongruent trials and number of errors made.

Backwards Digit Span Task (BDS). A series of digits (0-9) were displayed sequentially on the screen and participants were asked to report the digit sequence in
backward order. In total 14 series of digits were displayed, with lengths differing from three to nine digits. Dependent variables are the longest set remembered correctly and the total number of digits in correct sets.

Lighting Beliefs and Room evaluation. Lighting beliefs were assessed concerning effects of daylight on health, mood, vitality, and tension. The room was evaluated on lightness and to what extent participants would like to stay in the room for one more hour.

Procedure

After signing the informed consent form, ECG-electrodes were attached. They first received general instructions on the computer after which the experiment started with baseline mood questionnaire, psychophysiological measures (three minutes) and Stroop performance. After the baseline measurements, participants performed the typing task. After the typing tasks, the procedure differed between Part One and Part Two, see figure 1. Participants in Part One rated their mood (time 1) and waited for the next task to begin. For participants in part Two, either the automatic sunblind was opened (daylight condition) or a wall luminaire was turned on (artificial light condition) while participants waited for the next task to begin. In both parts, the total time elapsed between the typing task and the next task was one minute. The next part of the experiment the same for both parts and consisted of the Stroop task followed by a one-minute break and the backwards digit span task, after which they filled out the last mood questionnaire (time 3) and some further questionnaires. After the experiment had finished, they were thanked and paid (\in 7,50) for their participation.

Results

In Part One effects of Ego-depletion (depletion vs. non-depletion) as betweensubjects variable and Time (baseline versus time 1) as within subjects variable on mood, performance, and heart rate will be tested. In Part Two ego-replenishing effects of Light source (daylight vs. artificial light) as between-subjects variable and Time (baseline versus time 2) as within subjects variable on mood, performance, and heart rate will be tested.

General Discussion

In the present study we empirically investigated ego-replenishing effects of light. More specifically, we tested whether daylight has an additional beneficial effect over artificial light. Characteristics of daylight and artificial light were matched as closely as possible, however spectral differences can't be ruled out. Furthermore, as daylight conditions were always run before the artificial light conditions (this was necessary as daylight intensities were first measured,

then matched) possible temporal effects can't be ruled out either. However, we did make sure that light intensities were matched per condition and per part of the day, resulting in similar exposure in the morning and afternoon and between the two conditions. in replenishment Differences between daylight and artificial light will most likely be caused by psychological mechanisms as light intensities were matched in both conditions, ruling out any biological underlying mechanisms. Possible mechanisms as mood, beliefs about lighting, and preference for the lighting setting have been included in the study and enable further data analysis into the underlying process(es). If daylight can overcome ego-replenishment, this can have major implications for everyday life as self-regulation is related to many beneficial outcomes in life as for instance academic success, interpersonal effectiveness, and health.

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Bright Light Effects on Mental Fatigue

K. C. H. J. Smolders, & Y. A. W. de Kort

Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

During workdays, we use and deplete mental resources. Accumulation of effort spent throughout the workday might result in increased feelings of sleepiness, lack of energy, psychological stress and decrements in performance. Bright light, on the other hand, has been shown to positively impact alertness, vitality and performance and may thus counteract fatigue by helping recover decreased mental resources. In the present study, we investigate whether lighting (i.e., illuminance) particularly benefits office employees who suffer from resource depletion.

Research has shown that light is important for our wellbeing, health and performance. Light can, for instance, have both direct and phase shifting effects on people's circadian rhythm (see e.g. Dijk & Archer, 2009). In addition, studies have shown that exposure to higher illuminance levels can result in increased feelings of alertness and better performance at night (Cajochen, Zeitzer, Czeisler & Dijk, 2000; Campbell & Dawson, light shows 1990). Moreover, similar beneficial effects during daytime if individuals have first experienced substantial light or sleep deprivation (Phipps-Nelson, Redman, Dijk & Rajaratman, 2003; Rüger, Gordijn, de Vries & Beersma, 2006). A recent study by Smolders, de Kort and Cluitmans (2012a, 2012b) revealed beneficial effects of bright light exposure also during daytime under regular circumstances. This study showed that even in the absence of sleep or light-deprivation, higher illuminance at eye level can improve employees' alertness, vitality and objective cognitive task performance, and influence physiological arousal measured with heart rate, heart rate variability (HRV) and EEG. In the latter study, effects on subjective alertness and vitality, and physiological arousal were immediate and consistent during the hour of

bright light exposure. In contrast, the effects on performance and HRV were dependent on duration of exposure: These effects were most pronounced towards the end of the light exposure. A potential explanation for the delayed effect of bright light on cognitive performance is that more intense light improves cognitive performance mainly when participants suffer from mental fatigue. This is consistent with research showing that light exposure at night or among sleepdeprived participants can improve reaction times immediately (Phipps-Nelson et al., 2003; Lockley, et al., 2006). Furthermore, a lab study showed that participants who did not respond to exposure to a higher illuminance already had faster response times than participants who did, suggesting that they did not benefit from bright light because they already were very alert (Vandewalle et al., 2006). In the current study, we investigate whether daytime exposure to a higher illuminance level has an alerting and vitalizing effect mainly when a person is suffering from mental fatigue and resource depletion.

Method

Design

In the current study, a 2x2 within-subjects design (N = 28; 106 sessions¹) was applied to explore effects of two illuminance levels (200 vs. 1000 lx at eye level, 4000 K) after mental fatigue induction (fatigue vs. control). Participants came to the lab on four separate visits during the same timeslot in the morning (9:00am, 10:20am or 11:45am) or in the afternoon (1:15pm, 2:45 or 4.15pm). The conditions were counterbalanced across participants.

¹ Four participants were not able to participate in the fourth session and in two sessions the lighting did not work properly.

Baseline	Fatigue induction vs. control		C	Lighting condition	
Measures	MATB	Modified Stroop task		Maggurament block 1	Magguramont block 2
	Movie	Reading magazines	Stroop	Weasurement block 1	Nieasurement block 2
7 min	9 min	17 min	3 min 1	13 min	17 min
200 lx at desk (4000 K)				200 lx vs. 1000 lx at eye level (4000 K)	

Fig. 1: Schematic overview procedure.

Procedure

Before the start of each session, participants applied electrodes for heart rate, skin conductance and temperature measures according to the instructions given by the experimenter. Every session started with a 7minute baseline phase consisting of a 1minute rest period, performance tasks and a short questionnaire. Baseline performance was measured using three different tasks: A 3-minute auditory Psychomotor Vigilance task (PVT), a 1-minute auditory Go-NoGo task and a 1-minute 2-back task. After the baseline measurements, the mental fatigue vs. control manipulation started, which took about 29 minutes. After this, participants completed a short questionnaire. During the baseline measurements and fatigue induction, participants experienced 200 lx and 4000K at the work plane.

After the fatigue vs. control manipulation, participants were exposed to 200 lx or 1000 lx (at the eye) for 30 minutes. During this light exposure, subjective and objective measures were administered in two repeated measurement blocks. Each block started with a 1-minute rest period. Subsequently, performance was measured with a 5-minute auditory PVT, a 3-minute auditory Go-NoGo task and a 3-minute 2-back task. At the end of each block, participants completed a short questionnaire (see Figure 1).

At the end of each session, participants completed questions concerning subjective self-control, their evaluation of the lighting and the environment, time of going to sleep the night before, time of awakening and time spent outside. In addition, at the end of the last sessions, questions concerning person characteristics, such as light sensitivity, and chronotype trait vitality. were administered. Every session lasted 75 minutes and the participants received a compensation of 12,50 Euros per session.

Mental fatigue induction

Mental fatigue was induced with two demanding tasks: a 9-minute Multi-Attribute task battery (MATB) and a 20-minute modified Stroop task. The MATB is a multitask using a flight simulation in which the participant keeps track of multiple parallel processes (maintaining the volume in two fuel tanks, repairing the fuel system when broken, monitoring the aircraft, tracking the aircraft with a joystick, and adjusting the communication channel when needed). Participants were instructed to keep track of all parts and perform the tasks as well as possible.

After the MATB, participants engaged in a modified Stroop colour-naming task. Each word was presented for 1 second with a 2.2second interval between the words. For each word, participants had to indicate the colour of the ink by pressing the corresponding key on the keyboard, except when the word was presented in red in one version or in yellow in another version. In these cases, participants had to name the text instead of the ink.

In the control condition, participants watched a 9-minute nature movie and then read magazines for 17 minutes. At the end of the control condition, participants engaged in a 3-minute Stroop task with congruent trials.

Measures

Subjective sleepiness was measured with the Karolinska Sleepiness scale (KSS; Åkerstedt & Gillberg, 1990). Vitality and tension were assessed with six items selected from the Activation-Deactivation checklist (Thayer, 1989). In addition, two items assessing positive and negative affect (happy and sad) were administered in this questionnaire. Subjective state self-control was assessed at the end of each session using six items selected from the State Self-Control Capacity Scale (Ciarocco, Twenge, Muraven & Tice, under review). Three tasks were employed to assess cognitive performance. An auditory PVT assessed sustained attention. An auditory Go-NoGo task measured executive functioning and inhibition. In addition, a 2-back task was administered as a measure for working memory and executive functioning. During this task, characters were presented on the screen after each other and participants had to press the spacebar as fast as possible if the character presented was the same as two characters before. Each character was presented for 200 ms with an interval of 800 ms between two characters.

Physiological arousal was investigated using heart rate, skin conductance and temperature measures. These variables were measured continuously during the experiment using TMSi software.

Statistical analysis

Linear Mixed Model (LMM) analyses were performed with Lighting condition, Fatigue induction (fatigue vs. control) and Measurement block as predictors (separate analyses for each dependent variable). In these analyses, Participant was added as random variable to group the data per participant, i.e. to indicate that each participant was measured multiple times. To control for differences at baseline, the baseline measurement was added as covariate in the analyses. In addition, person characteristics were added as covariates to control for these variables.

Results

In this section, we will report the first results of the effects of Lighting condition and Fatigue induction on subjective measures of sleepiness, vitality, mood and self-control, and PVT performance.

Effects of lighting and fatigue induction on subjective measures

A manipulation check of the fatigue induction revealed that participants felt sleepier and less energetic immediately after the fatigue induction compared to the control condition (all p < .01).

Results during the light exposure revealed a main effect of Fatigue induction on subjective sleepiness and vitality suggesting that the effect of the manipulation on these variables lasted also during the light exposure (both p < .01).

Lighting condition had a main effect on subjective feelings of sleepiness (p = .02) and vitality (p < .01): Participants reported lower feelings of sleepiness and more vitality in the 1000 lx compared to the 200 lx condition. These results replicate the earlier findings by Smolders et al. (2012). For the current research question, we were mainly interested in the interaction between Lighting condition and Fatigue induction. This interaction approached significance for the KSS (p =.06) showing an effect of Lighting condition only after the fatigue induction (p < .01), but not after the control condition (p = .78). The interaction effect between Lighting condition and Fatigue induction on vitality was not significant (p = .59) suggesting that the effect on feelings of energy was not moderated by mental fatigue. Measurement block had no effects on the subjective measures (all p >.10) suggesting that the effects were immediate and consistent throughout the session.

Effects of lighting and fatigue induction on performance

Results of the PVT revealed that participants had slower reaction times after the fatigue induction compared to the control condition (p < .01). Lighting condition had no significant main effect on the mean reaction times of the PVT (p = .61). Measurement block had a significant main effect on the mean reaction times with slower responses in Block Two than Block One (p < .01). There was also a marginally significant interaction between Lighting condition and Measurement block (p = .06) suggesting a trend for slower reaction times in the 200 lx than in the 1000 lx condition only in Block Two (p = .06) and not in Block 1 (p = .33). The interaction between Lighting condition and Fatigue induction was, however, not significant (p = .84).

At the conference, the results of the Go-NoGo task and 2-back tasks will also be presented.

Discussion

The results of the current study suggest that exposure to bright light has an immediate and positive effect on subjective feelings of alertness and vitality. The effect on sleepiness was moderated by the fatigue induction, suggesting that 1000 lx (at eye level) had an effect on sleepiness only when the participants suffered from mental fatigue.

Although we expected a comparable direct effect of bright light on performance on the PVT when participants felt mentally fatigued, the effect of bright light on sustained attention seemed to only depend on duration of exposure. In line with results by Smolders et al. (2012),participants performed better on the PVT towards the end of the bright light exposure. Current study suggests a delayed effect of bright light on mental performance regardless of the mental fatigue status (fatigued vs. relaxed) prior to the light exposure.

Results of the other performance tasks and physiological measures will provide additional insights in the effect of bright light after mental fatigue during daytime and normal office hours.

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Fact or Fiction? Testing Effects of Suggested Illuminance Changes

K. C. H. J. Smolders, A. Antal, A. Corona, M. Heijboer, E. Keyes, K. Pollmann, & Y. A. W. de Kort

Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

Humans evolved as a diurnal species, functioning primarily during the daytime hours of the Earth's light-dark cycle with concomitant sleep-wake cycles that are governed by circadian and homeostatic processes. In contrast to our evolutionary ancestors, the behavioral settings in which most modern humans perform many workrelated tasks exist indoors and under artificial lighting; as light plays an important role in regulating physiological processes in humans, researchers are increasingly interested in exploring the effects of light in these settings. Research on effects of bright light during the night has rendered convincing evidence that light can elicit phase-shifting effects on the biological clock, increase nocturnal alertness and improve (Cajochen, cognitive task performance Zeitzer, Czeisler & Dijk, 2000; Campbell & Dawson, 1990; Rüger, Gordijn, de Vries & Beersma, 2006). Studies investigating such effects during daytime is more scarce, yet is also starting to show statistically significant effects on subjective as well as objective (physiology, task performance) indicators of alertness (Phipps-Nelson, Redman, Dijk & Rajaratman, 2003; Rüger et al., 2006; Smolders, de Kort & Cluitmans, 2012). The latter study showed that even under natural, i.e. non sleep or light-deprived conditions, a higher illuminance (1000 lx at eye level) can improve feelings of alertness and vitality, cognitive task performance, and influence physiological arousal during daytime.

Several mechanisms by which light might influence alertness and performance during daytime have been proposed (Rautkylä, Puolakka & Halonen, 2011; Stephenson, Schroder, Bertschy & Bourgin, 2012; Vandewalle et al., 2009). A possible mechanism for the alerting and vitalizing effects of light might be the activation and modulation of alertness-related and moodrelated pathways also referred to as nonvisual pathways. In addition, beliefs or expectations regarding effects of bright light may contribute to these effects. Thus, the effect can be purely biological, i.e. through activation of the central nervous system (Vandewalle et al., 2009), but could also be more psychological in nature - i.e. via the visual pathway, involving appraisal and affective routes (e.g. Veitch, Newsham, Boyce & Jones, 2008), or beliefs about activating effects of more intense light. These psychological pathways are relevant to theory, design and but also have methodological implications as participants in lighting studies are only rarely 'blind' to the light manipulation.

The current study was designed to test the effect of light via purely psychological (visual) pathways: we tested alertness and performance of participants who were scenarios, offered different lighting suggesting that the light was stable, increasing, or decreasing steadily, although in fact they were receiving equal amounts of light. We expected that if appreciation and/or beliefs play an important role in the beneficial effect of light, ostensibly increasing the intensity would affect alertness and performance more positively than exposure to a constant lighting scenario or ostensibly decreasing lighting scenario would. If, in contrast, the number of photons at the retina is the sole responsible cause, we would see no differences between the three lighting scenarios as participants in all conditions experienced the same light dosage.

Method

Design

In the current study, a between subjects design (N = 79) was applied to get insight in

the underlying mechanisms of the alerting and vitalizing effect of bright light exposure during daytime. In this experiment, the pattern of bright light exposure was manipulated such that it suggested a static vs. increasing vs. decreasing illuminance level, although the levels during the measurements were in fact identical (see Figure 1). We tested effects on both subjective and objective indicators of arousal as well as task performance during repeated blocks of exposure.

Procedure

Before the start of the session, participants applied electrodes for heart rate and skin conductance according to the instructions given by the experimenter. Every session started with a 7-minute baseline phase consisting of a 3-minute rest period, a 1.5minute auditory Psychomotor Vigilance task (PVT) and a 1.5-minute auditory Go-NoGo task, and a short questionnaire. During baseline, all participants experienced 1000 lx and 4000K at eye level. Subsequently, the were participants exposed to the experimental lighting conditions (at 4000 K) for about 40 minutes. The procedure is depicted in Figure 1.

During the experiment, subjective and objective measures were administered in three repeated blocks of 13.5 minutes. Performance was measured on two tasks: An auditory PVT and an auditory Go-NoGo task. Both tasks were administered in two parts of three minutes. In between the PVT and Go-NoGo task, participants had one minute to complete a short mood questionnaire. At the end of each block, participants had a 30second rest period in which the lighting changed ostensibly in the dynamic lighting scenarios, or remained constant in the control scenario.

At the end of the completed session, participants evaluated the lighting and the environment, reported time of falling asleep the night before, time of awaking and time spent outside, and person characteristics. In addition, participants indicated whether they noticed a change in the lighting, and described what they thought happened. The experiment lasted about 60 minutes and the participants received a compensation of 10 Euros.

Manipulations

In the static lighting condition, participants were exposed to a constant illuminance level (1000 lx at the eye). In contrast, in the experimental scenarios we introduced a fast and clearly noticeable up increasing) or (ostensibly downward (ostensibly decreasing condition) change in illuminance (to 1250 or 750 lx, respectively) at the beginning of each measurement block. In the following three minutes the illuminance level then gradually and unnoticeably returned to 1000 lx (see Fig. 1), and remained constant in all conditions for 7 minutes, during which the actual measurements were taken (3-minute PVT, 1minute questionnaire and 3-minute Go-NoGo task). In the last 3 minutes of each measurement block the illuminance level gradually and unnoticeably decreased or increased, in preparation for the sudden change at the start of the next block (see Fig. 1).

Measures

Participants performed tasks throughout the experiment, but only those during the constant (1000 lx) phases were used in analyses, allowing us to compare performance under identical light settings.

Subjective sleepiness was measured with the Karolinska Sleepiness scale (KSS; Åkerstedt & Gillberg, 1990). Vitality and tension were assessed with six items selected from the Activation-Deactivation checklist (Thayer, 1989). In addition, two items assessing positive and negative affect (happy and sad) were administered in this questionnaire.

Two tasks were employed to assess cognitive performance. An auditory PVT was used to assess sustained attention. During this test, a sound ('ni') was presented at random intervals of 1 to 9 seconds to the participant and the participant had to press the spacebar as fast as possible after hearing the syllable. An auditory Go-NoGo task was used to measure executive functioning and inhibition. In this task, syllables consisting of



Fig. 1: Lighting scenarios of the three conditions. The three black lines indicate the illuminance level during the control (upper), ostensibly increasing (middle) and ostensibly decreasing (lower) conditions, R = rest period and Q = questionnaire, m = measurement task performance.

a consonant and a vowel (e.g., 'na','ri','se') were presented at random intervals of 1 to 9 seconds to the participant and the participant had to press the spacebar as fast as possible after hearing 'ni', but not after hearing another syllable (20% of the cases).

Physiological arousal was investigated using heart rate and skin conductance measures. These variables were measured continuously during the experiment using TMSi software.

Linear mixed model analyses were performed with Lighting scenario and Measurement block as predictors (separate analyses for each dependent variable). In these analyses, Participant was added as random factor to indicate that each participant was measured multiple times.

Results

In this section, we will first report on the manipulation check. Subsequently we will report on the effects of Lighting scenario on subjective measures of alertness, vitality and mood, and on task performance. Physiological data have not been analyzed yet, but will be reported at the conference.

Manipulation check

As a manipulation check, we explored whether participants experienced a change in the lighting in the ostensibly increasing and decreasing scenario's, but noticed no change in the static condition. Results revealed that, as expected, participants in the dynamic scenarios perceived a change more frequently (95,7% in the ostensibly increasing condition and 96.3% in the ostensibly decreasing condition) than in the static lighting condition (3.7%) with $\chi^2(2, N = 77) = 64.54$ and p < .01. In addition, we investigated whether participants indicated that the light became brighter or dimmer during the experiment when they experienced a change. Figure 2 shows the frequencies of the perceived light changes and suggests that most participants perceived the lighting as becoming brighter in the ostensibly increasing scenario and becoming darker in the ostensibly decreasing scenario.



Effects of lighting scenario on subjective measures

Results revealed no significant effect of Lighting scenario on subjective feelings of sleepiness, vitality, or negative affect (p >.10), but a marginally significant trend for positive affect (p = .10) suggesting higher positive affect in the ostensibly decreasing condition compared to the other two lighting conditions. The interaction between Lighting scenario and Measurement block on negative affect was significant (p < .01) with an increase from Block One to Block Three in the ostensibly increasing scenario, but no significant changes in the other conditions. Investigation of only the data of participants who indicated to perceive the lighting as intended showed similar results.

Effects of lighting scenario on performance

Results of performance revealed no significant differences in reaction times on the PVT between the three lighting conditions. Results of the Go-NoGo task showed no significant effect of Lighting condition on mean reaction time, number correct, number incorrect and percentage correct. When we looked only at the data of participants who indicated to perceive the lighting as intended, the results revealed a marginally significant trend (p = .09) for a decrease in percentage correct in the ostensibly decreasing and static lighting condition towards the end of the light exposure, but not in the ostensibly increasing condition.

Discussion

We managed to ostensibly raise or lower illuminance levels for experimental groups, yet giving them the exact same amount of light as a control group. However, the results showed no significant differences in alertness, vitality, or performance between the three lighting scenarios. Participants did seem to report more negative affect when they thought the light was increasing and there was a trend for more positive affect in the suggested decreasing lighting scenario. There were some trends for an effect on the Go-NoGo task, but no consistent picture emerged.

The current study provided no indication that a suggested increase in illuminance level plays an important role in the effect of bright light exposure on subjective alertness and vitality, and task performance during daytime, but the data on heart rate and skin conductance may provide insights into whether suggested patterns of bright light exposure influence physiological arousal.

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User Experience of Automated Blinds in Offices

B. W. Meerbeek^{1,2}, E. J. van Loenen^{1,2}, M. te Kulve², & M. Aarts²

¹ Philips Research, Eindhoven, the Netherlands ² Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

The increasing attention for energy efficient buildings combined with technological advances in sensors, processing power, lighting, and networks drive the development of so called 'Smart Buildings'. In line with the Ambient Intelligence vision, it is expected that buildings will evolve into 'ambient intelligent office environments' (Aarts & Marzano, 2003). Technology will be embedded into the office environment, aware of our context, personalized to individuals, and adaptive and anticipatory to our needs. This vision is starting to become a reality in today's office buildings. Simple forms of building intelligence such as daylight-based occupancy sensing or dimming are already common practice.

There are clear economical drivers for ambient intelligent office environments. For example, the energy and cost savings that can be made by automatically switching off the light when people are not in a room or by dimming the electric light if sufficient daylight is available. The intelligent behavior should not only result in energy and cost savings, but also make sure that occupants are satisfied with and feel in control of their working environment. However, automation might reduce this feeling of control. If decisions are based solely on economic criteria such as energy saving, the resulting conditions might not be beneficial for the comfort of occupants. A balance between energy efficiency and comfort needs to be found.

As a large part of the population spends a significant part of the day in an office environment, it is not surprising to see an increasing awareness of user comfort in office buildings. Besides the positive effects of a comfortable work environment on the health and wellbeing of office workers, studies have shown correlations between the level of comfort and job satisfaction, and even productivity (Boyce, 2003). Hence, there are also economic reasons for employers and building owners to focus on comfortable work environments.

Although comfort is a subjective concept. much research has been done on objective determinants and measures of comfort. Many aspects have been identified that influence perception of comfort in offices, the environmental including aspects (e.g. building characteristics, climate), social aspects (e.g. relationships with colleagues), and personal aspects (e.g. gender, age) (Bluyssen et al., 2011). It is unclear how all of these different aspects relate to each other and contribute to an overall perception of comfort, but studies have shown the importance of individual aspects such as daylight and electric lighting on perception of comfort. The perception of control is an psychological important process that influences perceived lighting quality and satisfaction with the working environment (Veitch, 2001).

In this paper, we report our work on the user experience of automated daylight control systems in relation to occupants' perceived comfort with the indoor climate. But first, we discuss related work.

Daylight, Blinds, and Control

People generally have a clear preference for daylight over artificial lighting as a source of illumination (Boyce et al., 2003; Cuttle, 1983). Studies have shown this preference for daylight also in offices for various reasons. including enhanced psychological comfort, increased productivity, office more pleasant appearance, and assumed health benefits (Heerwagen & Heerwagen, 1986; Veitch & Gifford, 1996). Hence, it is not surprising



Fig. 1:Office building at the High Tech Campus (left), 2-person office with internal shades and external blinds (center), blinds controller in the office (right)

that Christoffersen (2000) and others found that people prefer to sit near windows. The most positive aspects of a window according to this study in twenty Danish buildings are to have a view out, to be able to check the weather outside, and to have the ability to open the window. But windows can also be a source of visual and thermal discomfort and therefore they mostly come with blinds.

Previous studies show that people do not regularly change the blinds positions manually: they lower them to block direct sunlight, but seldom raise them again for daylight entrance, energy saving or view (Galasiu & Veitch, 2006). Interestingly however, Reinhart and Voss (2003) found that in 88% of the cases when the blinds lowered automatically, people manually raised them within 15 minutes. They also found that people are more likely to accept automatic raising than automatic lowering of blinds. A study by Lindsay and Littlefair (in Galasiu & Veitch, 2006) showed that some blinds were hardly ever used while other blinds were used > 70% of the days studied.

As a result of the technological advances and increasing focus on energy efficient buildings as mentioned before, automatic daylight management systems are being developed. The algorithms for the blinds behavior are often optimized to achieve maximum energy saving in simulations. But what about user comfort? How do occupants experience and use these systems in a real office setting? In the remainder of this paper, we report our field study to investigate how experience workers office a current implementation of an automated daylight control system.

Research method

We conducted contextual research using a diary study and semi-structured interviews with building occupants on satisfaction with the indoor climate, focusing on the blinds usage. The study was setup in two-person offices at the south façade of a building on the High Tech Campus in Eindhoven (see Figure 1). The selected offices were located at the 3rd, 4th, and 5th floor with an unobstructed view on natural scenery including several buildings. The façade is equipped with motorized blinds that can be controlled automatically per segment of the building and/or manually per room. These blinds are lowered automatically if the rooftop light sensors detect intensities exceeding a threshold value (16kLux) and raised at fixed times (21:00) or with high wind speeds. Furthermore, each room is equipped with three manually operable indoor shades and one controller for the exterior blinds. With this controller, occupants can choose to set the blinds in automatic or manual mode and use up and down keys to manually control the blinds. Each room is equipped with fluorescent lighting automatically controlled based on occupant presence (on/off) and daylight linked dimming. Occupants are not able to manually adjust the artificial light. The daylight linked lighting is setup to provide a constant 500 lux on the desk.

Given our interest in the experiences of building occupants with the automated blind system, we selected two groups of blinds users for our study: 9 'automatics' (in 5 offices) and 8 'manuals' (in 5 offices). These groups were formed based on their current setting (on automatic or manual) of the switch as shown in Figure 1 on the right. By having both groups in our study, we expected to get a rich picture of the user experience of automated blinds for various user types.

The 17 occupants in the 10 selected offices were asked to fill in a diary during 10 working days, from the 23rd of November till the 6th of December 2011. The diary started with an introduction and explanation of the study, followed by a questionnaire about general personal information. Each day, the participants judged the indoor climate on the following aspects: daylight, artificial light, temperature, air quality, and room acoustics. Furthermore, they listed all their blind adjustments, including the reasons for making the adjustments. The participants judged the indoor climate only if they were present that day, so the number of responses differs per day. At the end of the day, the participants made an overview of their activities in the office. After ten working davs. the researchers interviewed the participants to discuss their answers in the diary and ask additional questions on comfort of the working environment and the automated blind system.

Results

The study was held on 10 working days from 23^{rd} of November until 6th of December (excluding the weekend) in the Netherlands and included 3 days without sunshine, 5 days with less than 30% sunshine duration, and 2 days with around 60% of sunshine. Global radiation and sunshine duration data is presented in Table 1.

Table 1 Weather data

	10-day average	minimum	maximum
Global radiation (J/cm2). Daily average	22	8	36
Global radiation (J/cm2). Daily maximum	61	17	92
Sunshine duration	22%	0%	66%

In total, 112 blind adjustments were recorded in the 10 selected offices during the ten working days of the study. Table 2 shows the distribution between automatics and manuals and the type of blind adjustments. For example, the number in the row 'Down user' and column 'Auto' shows that four times an automatic user manually lowered the blinds. The table shows that manuals have more adjustments in total than automatics (62 vs 50) and, as expected, more manual adjustments (62 vs. 10)

Prevention of discomfort glare was the most frequently mentioned reason for lowering (70% of all manual lowering events) or rotating the blinds (55% of all rotating events). Thermal comfort was only mentioned in 5% of the manual lowering events. For raising the blinds, the most frequently mentioned reason is to create a view outside (52% of all manual raising events). In 35% of the manual raising events, a lack of light in the room was mentioned. Some less frequently mentioned reasons for raising the blinds are appreciation of direct sunlight or too strong wind. In 68% of the manual adjustments, participants were alone in the office, and in 32% of the cases their roommate was present.

There was no significant difference in the overall satisfaction with the indoor environment between automatics and manuals (7.8 and 7.7 on a 10-point scale). Zooming in on specific elements of the indoor environments, the participants were least satisfied with (1) daylight, followed by the (2) room temperature, (3) artificial lighting, (4) air quality, and (5) room acoustics. 27% of the participants judged the daylight as uncomfortable. For artificial lighting, this percentage is much lower (4%).

Table 2 Number of blind adjustments

	Auto	Manual	Sum
Up system	7	-	7
Up user	4	21	25
Down system	33	-	33
Down user	4	29	33
Rotate	2	12	14
Total	50	62	112

During the interviews, participants mentioned the importance of interaction with the outside: daylight, sunlight and a view. People accept some glare to get daylight in their room. Nobody answered that the automatic function works properly. Blinds go down when people do not want them to and vice versa. Automatic users mentioned that as well, but they still put the blinds system on automatic. They do not want to spend time on adjusting the blinds and rather change the position of their screen or chair to prevent discomfort glare. Daylight entrance is a very important reason to open the blinds. It is also a reason to postpone lowering the blinds and accept more glare. Most manuals say they raise the blinds when glare has disappeared. Automatics say they like daylight but just do not think of raising the blinds again. Nobody mentioned that concerns about energy usage influence their usage of the blinds system. They mainly adjust blinds to create a visually comfortable workplace.

Conclusion and discussion

People in working environments lower blinds mainly to prevent discomfort glare and raise blinds to create a view outside or increase daylight entrance. This is in line with earlier findings reported in other studies (Galasiu & Veitch, 2006). The average amount of blind adjustments during our study is 1.12 per office per day.

The overall comfort level between automatics and manuals in our study did not differ. All occupants expressed to feel in control of the blinds system. Even the automatics, since they could still manually override the system if they wanted to. This suggests that it is rather the *perception of control* rather than the objective amount of control that affects user comfort.

We did see a bit more spread in the comfort ratings of manuals. They tend to be more aware of or concerned with the indoor climate than automatics. This was confirmed during the interviews and also for example by the number of blind rotations. Most automatic users say the automatic function does not work properly, but they do not want to spend time on adjusting the blinds and rather accept some discomfort. Manual users decide to switch off the automatic mode and take manual control over the blinds.

Daylight, sunlight, view and the perception of control are important elements that affect comfort levels in working environments. This should be considered when designing the algorithms of intelligent blinds. while maintaining energy requirements as boundary conditions for the blinds behavior. If not, people will switch automatic blind systems off which leads to suboptimal indoor climates, user comfort and usage office energy in buildings. Furthermore, one should acknowledge the different type of blind users and tailor the solutions towards these different usage patterns.

This diary study and interviews provided useful initial insights on how occupants experience and use automatic blind systems. As a next step, we want to combine the current findings with the blind usage data of 45 offices in the same building that we collected over a longer period (from July to December 2011) to provide more detailed blind usage data for various weather conditions.

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Poster

Non-linear Adaptive Lighting Model as a More Holistic Approach to Urban Lighting Design

E. Gonçalves¹, A. M. Ferreira¹, & H. Christiaans²

¹ UNIDCOM/IADE, Lisbon, Portugal ² TU Delft School of Industrial Design Engineering, Netherlands

Introduction

The way we currently use the nighttime space is changing rapidly (Tillett, 2011). As current lighting systems, generally, do not respond to these social changes, their is a need to devise new concepts and approaches (Ritter, 2006). From this framework the research question arises: Is it possible to develop new theoretical models, that considers adaptive light, as a way to ensure a more effective control and response to user-centred needs. maintaining or enhancing the sense of security and well-being in urban space?

Hence, the main goal is the development of an analysis tool (model), that can support the creation of more tailored and flexible lighting solutionshen, than current ones, in relation to the location. This approach, should provide a broad empirical basis for the conceptual interpretation of the designer.

Proposed Model

Perception of space and time is as vital to our biorhythm (Burnett, 2011) as it is to the understanding of our surrounding. This is linked to the natural movement of shadow and light variation along the daytime and over the seasons (Narboni, 2004). According to Madsen's (2006) concept of *Ligh Zones*, it is more appropriated to refer to light as being all the different levels of shadow in between light and darkness.

The model will promote the correlation of light modulation - through the use of four main lighting variables: brightness, colour temperature, direction and distribuition (Madsen, 2006) - with analysis methods for user and space perception (Pont, 2012; Van Bilsen, 2008; Tillett, 2011). Structured into two groups of layers that interact at different levels: one *analytical* and one *responsive*.

Validation method

We will resort to mix methodological approach. In a first moment, supported on bibliographic and case study review, and on a second, validation through a quasiexperiment in laboratory (Pont, 2012), (Flynn, 1979) and in a full-scale outdoor experiment (Lindh, 2011). The objective is to measure the subjective impressions of light in the users in an outdoor pedestrian spaces.

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Intelligent Street Lighting and Perceptions of Personal Safety

L. van Rijswijk, A. Haans, & Y. A. W. de Kort

Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

Street lighting in its present-day form serves various utilitarian purposes, such as the prevention of crime and traffic accidents, or providing people with a sense of safety when they walk down the street at night. However, in light of the discussion on climate change, fossil fuel reserves, and light pollution, conventional street lighting systems are currently also the subject of considerable debate (e.g., because they waste energy by providing light when there are no street users). One solution is the implementation of LED lamps, which are not only more energy-efficient, but also allow the fluent control of output levels. These characteristics of LEDs make possible the dimming of street lighting when there is less demand or need.

Nevertheless, the goal of saving energy can also undermine a major purpose of street lighting: providing people with a sense of safety. Intuitively, we feel that there is a trade-off to be made between the dimming of lights (and thus a reduction in energy usage) and the sense of personal safety that people experience when they walk down the street at night. Such a tradeoff can be attenuated by integrating sensing technologies to recognize the number, type, and location of street users. This will result in intelligent street lighting systems that can adapt continuously to the environment and provide lighting where it is needed, while selectively dimming the rest of the environment.

However, the implementation of these new types of lighting systems, capable of intelligent selective dimming, is not as straightforward as it may seem. The main issue is that we do not yet have a sufficient understanding of how (street) lighting affects people's sense of safety to determine which important areas should be lit and which areas can be dimmed without affecting subjective appraisals of safety.

In the current paper we aim to (a) provide the reader with a short overview of relevant literature on the effects of street lighting on both objective and subjective safety, and (b) identify the most important issues that need to be resolved in order to reach a comprehensive understanding of the mechanisms underlying lighting effects on perceived personal safety.

State of the art I: Street lighting and crime

There is a substantial body of literature investigating the effects of street lighting interventions on objective measures of safety (e.g., crime rates). Yet, this body of research is characterized by considerable debate. For example, early Home Office reviews (e.g., Tien, O'Donnell, Barnett, & Mirchandani, 1979) have reported absolutely no effects of street lighting on the deterrence of criminal behavior. In a reaction to the apparently diverging conclusions from Home Office reviews and other studies which did show marked effects on deterrence of crime, Pease (1999) has criticized the Home Office reviews, for example for relying too much on a single evaluation study (i.e., Atkins, Husain, & Storey, 1991) - a study performed by the Home Office which he subsequently criticized for being methodologically flawed (for the complete criticisms, see Pease, 1999).

In a recent meta-analysis, Welsh and Farrington (2008) compared the effects of 13 different studies on lighting interventions, and concluded that these interventions indeed significantly decrease overall crime rates. A majority of the studies under consideration reported significant decreases in crime rates, while the remaining studies reported neither decreases nor increases in crime rates. The carefulness displayed by Welsh and Farrington in selecting which studies to include (e.g., the studies required before-andafter measures) and the criticisms on the Home Office reviews at least appear to lend some credibility to the conclusion by Welsh and Farrington's meta-analysis. Thus, at present, it seems safe to conclude, in spite of relatively mixed evidence (see also Boyce & Gutkowski, 1995), that street lighting interventions can be relatively successful in decreasing crime rates. This conclusion seems to fit the popular intuition that street lighting acts as a deterrent of criminal behavior by making criminal acts more visible.

However, there are some findings that do not quite fit such a simple explanation of lighting effects on crime. For example, some of the studies described in the Welsh and Farrington (2008) meta-analysis report that lighting interventions lead to decreases in crime rates during nighttime as well as during daytime. The lack of explanations offered for these kinds of findings points out a hiatus in our understanding of how lighting affects crime. There may yet be many more factors that play a role in explaining the effects of street lighting implementations on crime rates (e.g., social capital, see Pease, 1999).

In addition, the objective risks that an individual is exposed to do not necessarily have to correspond to an individual's subjectively experienced personal safety (e.g., Vrij & Winkel, 1991). Since we are mostly concerned with how street lighting affects *subjectively experienced feelings* of safety, we now turn to a short overview of relevant literature on the effects of street lighting on more subjective measures of safety.

State of the art II: Street lighting and perceived personal safety

For the sake of clarity in discussing the effects of street lighting on subjective safety, we define a person's perceived personal safety here as a person's immediate sense of security, or an absence of the anxiety of becoming a victim of crime, when traveling through an environment. People's subjective appraisals of personal safety can have a profound impact on their felt freedom to go out at night. For example, Warr observes that decreases in people's perceptions of safety lead to an increase in the number of people who avoid leaving their home after dark, most prominently in urban areas (e.g., Warr, 1990).

An important question then is whether street lighting interventions can influence people's perceptions of safety. Interestingly, the same Home Office reviews that reported no significant effects of street lighting interventions on crime rates do report (somewhat cautiously) that street lighting may affect the public's fear of crime (e.g., Tien et al., 1979). Further evidence is presented by Painter and Farrington, who have collected extensive data during several studies evaluating the subjective impact of street lighting interventions (e.g., Painter, 1994; Painter & Farrington, 1999). Their research strategy included assessing both people's attitudes toward specific criminal behaviors as well as measures targeted at assessing behavioral consequences (e.g., counting the number of pedestrians using the street) and they consistently found that lighting improvement programs resulted in a decrease in people's fear of crime and an increase in pedestrian street use at night (but see Boyce & Gutkowski, 1995 for a critical discussion of these studies).

The broad conceptualizations of 'street lighting interventions' in the aforementioned studies do not necessarily provide an answer to the practical question of how street lighting should be designed to positively affect people's sense of safety. Boyce and Gutkowski (1995) offer some (mixed) evidence on this issue in their review on the effects of street lighting on street crime. The authors discuss several studies and cautiously offer some general recommendations, for example on adaptation luminance (vertical illuminance should be in the range of 10 to 30 lx) and illuminance uniformity (average horizontal illuminance should be 5 lx, with a minimum of 2.5 lx).

An interesting reflection on the studies highlighted above (and, more in general, many studies investigating the impact of street lighting on subjective measures of safety) is that while the findings seem to suggest that street lighting indeed influences people's perceptions of personal safety, they generally do not provide any empirically grounded answers to the question how street lighting affects safety perceptions. Some authors have proposed an explanation for their findings. For example, Boyce and Gutkowski suggest that the major factor mediating the effect of lighting on safety perceptions is the extent to which people are able to perform long-range detection of possible threats and make confident facial recognitions of other people on the street. On the other hand, Painter (1994) lists altered perceptions due physical public to improvement of the environment, increased social dynamics (related to social capital, see Pease, 1999), and a "general feel good factor" (p. 118) among the possible ways in which street lighting could increase safety perceptions.

However interesting these suggestions (and others) may be, there is no empirical work known to us that provides solid evidence for any of the suggested alternatives. We believe that, in the light of developments in (street) lighting new technology, it is essential to advance our understanding of how street lighting affects cognitions, emotions, people's and, ultimately, their behavior. To this end, we have identified two main issues that should be addressed by future research investigating the relationship between lighting and safety perceptions.

Current issues

The perception of safety

On a very basic level, the first issue is that we need to understand how people arrive at an interpretation of their environment. Or, more in terms of our interests, how do people form their perception of personal safety? Viewed from an environmental perspective, the question remains how people perceive and process environmental features (e.g., Brunswik, 1952; Gibson, 1979) and how these interpretations subsequently influence how people assess certain environmental qualities. Gaining a good understanding of how safety perceptions come into existence is an essential theoretical condition for investigating how specific objective environmental features and subjective environmental appraisals may influence these perceptions.

One way to look at this is by adopting a functionalist approach to environmental preferences (e.g., Appleton, 1975; Kaplan & Kaplan, 1989), which entails the assumption that people prefer environments that offer opportunities to fulfill human needs crucial to our survival. From this perspective, safety may be regarded as one of the most important basic needs and people should prefer environments that maximize their potential safety.

According to Fisher and Nasar (1992), who elaborated on Appleton's prospectrefuge model, people's safety feelings result from their subjective appraisal of three safety-related characteristics of a street (soproximate called cues): prospect, concealment and escape. The findings from their studies show that people feel more safe in environments that offer (a) a good overview of the situation (or good prospect), (b) minimal opportunities for possible offenders to hide (or low refuge), and (c) enough escape routes (or high in escape). The application of this framework provides us with a basic understanding of what (subjective) aspects of an environment may be important when it comes to people's judgments of personal safety, and thus proves to be a fruitful starting point for conducting further research. Nevertheless, this theoretical framework cannot fully explain the psychological mechanisms underlying environmental assessments. Put differently, we may now have some knowledge on how these perceptions come to be, but we still do not understand why.

Street lighting and perceptions of safety

A second issue then is to understand the role of lighting, or the relationship between street lighting and perceptions of personal safety. Although this relationship seems intuitively strong, literature on the subject is quite limited and indecisive. In light of the prospect-refuge model (e.g., Fisher & Nasar, 1992), lighting may be regarded as an objective characteristic of the environment. Yet, how does it affect the more subjective proximate cues and thus people's safety perceptions? When we think about it, street lighting is a somewhat ambiguous concept; on the positive side, it provides people with good vision at night, but light also casts shadows. These diverse effects can affect our sense of safety in a number of ways, and we just do not know whether the balance in the end is positive or negative. Do we actually need street lighting at all to feel safe?

Conclusion

The main aim of this paper was to bring together literature, providing the reader with a basic frame of reference to understand the relationship between street lighting and people's sense of safety. Our discussion has provided us with some valuable insights, but the main insight has been that we do not yet have sufficient knowledge of the mechanisms underlying the relationship between street lighting and people's perceived personal safety to draw any definite conclusions. However, with an eye to future research, we have identified some important issues; we need to (a) gain a deeper understanding of how safety perceptions come into existence and (b) investigate in which ways lighting influences these safety perceptions. Only then will we be able implement adaptive lighting systems that both reduce energy usage and continue to serve all the functions they are intended for.

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Sunlight versus Electrical Lighting: A Naturalness Bias in People's Appraisal of Light

A. Haans, & K. C. M. Olijve

Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

Study 1

In a recent interview, the German light designer Ingo Maurer expressed his dismay regarding the recent European ban on the incandescent light bulb: "The incandescent light bulb, same as the sun, emits light by means of heating. In its warm glow all colors are reproduced, people look healthier, food tastes better, and one gets tired less easily. Now we are stuck to energy saving lamps and other types of synthetic light" (Hollands Diep, 2009/2010; p. 158). Interestingly, the light emitted by an incandescent light bulb is regarded as less artificial, than that emitted by modern energy saving lamps. A similar preference for products that are perceived as more natural exists in other domains, including food and medication. Here, this preference is called the naturalness bias (e.g., Rozin, 2005; DiBonaventura & Chapman, 2008). It is considered a cognitive bias as people prefer the natural option (e.g., a drug extracted from plants) even when its synthetically produced counterpart is exactly identical on the molecular level.

In the present paper, we present three studies in which we investigate whether a similar naturalness bias exists in people's appraisal of light. In the first study, we investigate whether the concept "natural" is meaningful in people's appraisal of light. For this purpose, we estimate the perceived naturalness of various types of light as emitted from different sources. We expect that light emitted from the sun is consistently regarded as more natural than electrical lighting, but that even sunlight may lose some of its naturalness when it passes through windows, or is reflected by mirrors. A comparable finding is reported by Rozin (2005), who found that the manipulation of food affects how natural a food product is perceived.

Method

Sixty-three persons participated in this laboratory experiment. The mean age was M = 23.1 (*SD* = 18.1; range 18 to 75); 41of which were men. All participants received 2.00 Euro as compensation.

Each participant compared 11 different types of light with regard to its naturalness using forced-choice pair-wise comparisons (see Table 1). The E-Prime 2.1 software (Psychology Software Tools, Pittsburgh, PA) was used for presenting the light type descriptions, and for recording responses. Each participant completed all of the 55 possible comparisons. Each time, participants were instructed to indicate which light they perceived as most natural. Responses were analyzed with the many-facet Rasch model, using the Facets software (Winsteps.com). This method of analysis is similar to Thurstonian scaling.

Results & Discussion

The estimated perceived naturalness of each of the 11 types of light is provided in Table 1. We found significant differences between most pairs of light types, with p < p.05 (see Table 1). Sunlight entering through an open window was regarded as most natural. As expected, the medium through which sunlight passes significantly affected its naturalness: When entering a room through clear glass, or more so for blinded or translucent glass, it was considered to be less natural than when entering through an open window. Sunlight, however it entered a room, was considered more natural than light from artificial light sources, except for the daylight simulator which was regarded about as natural as sunlight through blinded, or translucent glass. Of the electrical light sources, our participants regarded the

Table 1: Perceived Naturalness of 11 Types of Light (in Logits), Standard Errors of Estimate (SE), and 95%-Confidence Intervals.

Light source		Naturalness	SE	95%-CI
1.	Daylight entering through a hole in the wall (e.g., open window) ^a	5.96	0.35	5.27 to 6.65
2.	Daylight entering through a clear window ^b	4.06	0.28	3.51 to 4.61
3.	Light emitting from a daylight harvester on the roof that brings daylight into the room using mirrors ^c	0.89	0.14	0.62 to 1.16
4.	Light emitting from a daylight simulator, powered by the energy grid (grey energy), that mimics daylight perfectly in all its aspects ^d	-0.17	0.11	-0.39 to 0.05
5.	Daylight entering though a blinded or translucent window ^d	-0.23	0.11	-0.45 to -0.01
6.	Light emitting from incandescent bulbs powered by solar panel ^e	-0.68	0.1	-0.88 to -0.48
7.	Light from energy saving light bulbs powered by energy grid (grey energy) ^f	-1.48	0.1	-1.68 to -1.28
8.	Light emitting from incandescent bulbs powered by energy grid (grey energy) ^f	-1.67	0.1	-1.87 to -1.47
9.	Light emitting from white solid state (LED) lamps powered by energy grid (grey energy) ^f	-1.73	0.1	-1.93 to -1.53
10.	Light emitting from fluorescent (TL) tubes powered by energy grid (grey energy) ^g	-2.45	0.11	-2.67 to -2.23
11.	Light emitting from colored solid state (LED) lamps powered by energy grid (grey energy) ^g	-2.51	0.12	-2.75 to -2.27

Note. Different superscript letters indicate significant differences with p < .05*.*

incandescent light bulb as emitting the most natural light, at least when powered by a solar panel. The fluorescent (TL) tubes and colored solid state (LED) lamps were regarded to emit the least natural light.

Study 2

Having established that the concept "natural" has meaning in people's appraisal of light and light sources, we will now test whether this may indeed lead to a cognitive bias in people's decision making. For this purpose, we use a decision making paradigm common in research on the naturalness bias. Additionally, we take into account a recent alternative explanation for the naturalness bias: That it results from people not believing that synthetic products can be identical (e.g., on the molecular level) to their natural counterparts (Li & Chapman; in press).

Method

One-hundred persons were contacted via email to fill out an online questionnaire. Seventy-six of them completed the survey. The mean age was M = 29.5 (SD = 8.6; range 16 to 63); 33 of which were men. They received 1.00 Euro as compensation.

The survey consisted of three questions. First, participants read descriptions of two rooms, and selected the room (A or B) they preferred most:

"Room A is lit up with light from a daylight harvester. This is a device on the roof which collects the sun light and transfers it using mirrors into the room".

"Room B is lit up with light from a daylightsimulator. This is a ceiling lamp (powered with electricity from a solar panel) that mimics daylight perfectly in all its aspects".

They were instructed to focus on the quality of the light in the room, and to ignore the specifics of the luminaire (e.g., costs or energy consumption). The order of the rooms, and thus the labeling of the rooms, was counterbalanced across participants.

Subsequently we asked participants to reflect on why they chose a particular room (i.e., A or B). All but three of the participants answered this question. Finally, people were asked to read a description of a new daylight simulator in which it was claimed that the emitted light is identical to daylight in all its aspects. Participants indicated how strongly they believed in this claim using a 10-point scale ranging from 1 (not at all credible) to 10 (absolutely credible).

Results & Discussion

Contrary to our expectations, we did not find a clear preference for light from the daylight harvester (i.e., 57%) over light emitted by the daylight simulator, with p =.30 (Binomial test). The credibility of daylight simulation cannot explain the, in this case, absence of a naturalness bias. On average, our participants did not strongly believe that a daylight simulator can emit light that is identical to natural daylight, with an average credibility of M = 6.1 (SD = 1.7). Moreover, the perceived credibility of daylight simulation did not correlate with an individual's choice of rooms, with $r_{pt-biserial} =$.08 and p = .50.

Our participants' comments on why they chose a particular room, however, proved more insightful. We identified three main themes: naturalness-related reasons, practical reasons, and comments indicating that people did not fully understand daylight harvesting. Sixty-five of the 73 comments could be classified under one or more of these themes.

In total, 56.6% of the participants gave a naturalness-related reason. Typical such comments were "Rather real sunlight, than something that mimics it" or "The daylight harvester provides pure sunlight, not simulated sunlight". A statistically significant proportion of these people chose the daylight harvester room (p < .01; Fisher's exact test). At the same time, 21.1% of the comments included practical reasons for not preferring the daylight harvester, such as "With the simulator, one is not 100% dependent on the sun", or "A daylight simulator also works during the evening". A marginally significant proportion of these participants chose the daylight simulator room (p = .08). Finally, 14.5% of the comments reflected that participant did not fully understand the concept of a daylight harvester: "I cannot imagine a room full of mirrors" or "Mirrors that reflect sunlight will be too bright." Taken together, these results indicate that a naturalness bias may exist in people's appraisal of light, but that functional aspects of the lighting and a misunderstanding of daylight harvesting may have confounded the results. Therefore, we repeated Study 2 with slight changes to the questions.

Study 3

Method

A different group of 100 persons were contacted via email to fill out an online questionnaire. Seventy-seven completed the survey. The mean age was M = 28.4 (SD =6.7; range 20 to 54); 39 of which were men. They received 1.00 Euro as compensation.

As in Study 2, participants were asked to select the room (A or B) they preferred most:

- A: of the total amount of light during a day:
- 80% is extracted using a so-called daylight harvester on the roof, which collects daylight and transfers it into the room using glass fiber.
- 20% is generated with a daylightsimulator (powered with electricity from a solar panel) that mimics daylight perfectly in all its aspects.
- *B*: of the total amount of light during a day:
- 80% is generated with a daylightsimulator (powered with electricity from a solar panel) that mimics daylight perfectly in all its aspects.
- 20% is extracted using a so-called daylight harvester on the roof, which collects daylight and transfers it into the room using glass fiber.

The instructions were similar to Study 2, but we stated explicitly that the total amount of illumination was similar for both rooms. This time, we also included an image of what the luminaires in the rooms may look like (see Figure 1).

In the remainder of the article we will call room A the daylight harvester room, and room B the daylight simulator room. Consistent with our naturalness bias hypothesis, we expect people to choose the daylight harvester over the simulator room. The remainder of the questionnaire and the



Fig. 1: The photograph of a ceiling luminaire as used in Study 2 to illustrate to participants how the lighting system in rooms A and B may look.

classification procedure for the comments to the open question were similar to Study 2.

Results & Discussion

Consistent with our naturalness bias hypothesis, a larger proportion of participants preferred the daylight harvester (69%) over the daylight simulator room, with p < .01(Binomial test). As before, most (50.6%) of the people stated naturalness-related reasons. This time, only 6.5% of the participants mentioned practical reasons, and only one comment was categorized as reflecting a misunderstanding of daylight harvesting. In contrast to Study 2, we found no significant differences in choice behavior between people that did or did not make a certain type of comment ($p \ge .17$).

As in Study 2, our participants, on average, only moderately believed that a daylight simulator can emit light that is identical to sunlight, with M = 5.7 (SD = 2.0; range 1 to 9). This time, we found a small correlation between perceived credibility of daylight simulation and room choice, with $r_{pt-biserial} = -0.29$ and p < .01. A stronger belief in daylight simulation makes people less prone to choose the naturally framed option. This small correlation, however, cannot explain wholly the observed choice behavior.

General Discussion

Taken together, the three studies make our hypothesis plausible that a naturalness bias exists in people's appraisal of light. As expected, we found sunlight to be perceived as more natural than electrical light, and that the manner and degree in which sunlight is transformed, for example by reflective surfaces, decreases its perceived naturalness. Additionally, we provided evidence that perceptions of naturalness may indeed lead to a cognitive bias in people's decision making with respect to light.

The naturalness bias in people appraisal of products is generally explained to have an ideational (i.e., a normative) and/or an instrumental basis (Li & Chapman, in press). We are currently investigating whether the preference for natural light is mostly normative, or is grounded in people's instrumental beliefs with respect to the mental and behavioral consequences of being exposed to sunlight (e.g., with respect to health, performance, and concentration; see, e.g., Veitch, Hine, & Gifford, 1993).

There are two limitations to the present studies. First, we relied solely on written descriptions of light, rather than on direct experience with it. Second, we focused exclusively on people's appraisal of light. It would thus be interesting to test whether perceptions of naturalness also affects the behavioral outcomes of being exposed to different types of light (e.g., performance).

Despite these limitations, our results are of potential interest to light designers and manufacturers, and to researchers interested in the psychological effects of light on people.

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Prescribing for Daylight: Can We Account for the Disparate Measures Within a Unified Modelling Framework?

J. Mardaljevic¹, & M. Andersen²

¹ School of Civil & Building Engineering, Loughborough University, Leicestershire, LE11 3TU,UK ² EPFL ENAC IA LIPID, Lausanne, CH - 1015, Switzerland

Introduction

The potential for a building design to provide daylight for general illumination was, until very recently, evaluated using only the daylight factor, i.e. a ratio of internal to external illumination under а single standardised overcast sky. Other known effects of daylight, such as the occurrence of visual discomfort which is more likely to occur during non-overcast conditions, were assessed or estimated by other means, often relying more on the skill of the experienced lighting designer than by use of a repeatable set procedure. In the last few decades there has been a gradual increase in awareness of the non-visual effects of daylight/light received by the eye Webb (2006). The quality and nature of the internal daylit environment is believed to have a significant effect on human health in addition to general well-being and worker productivity.

Demonstrating compliance with various guidelines at the design stage is an ever increasing concern. For daylight this is invariably carried out nowadays using simulation rather than scale models. After many decades of reliance on the daylight factor as the sole quantitative daylight metric, there has been an explosion of activity in daylight modelling research which has delivered numerous new techniques, approaches and metrics. This paper describes various end-user requirements - both current and emerging - for daylight modelling and discusses how these might be accommodated within a single modelling framework.

End-user requirements

End-user requirements will vary greatly depending on their needs. Does the user want to "understand" the spatio-temporal dynamics of illumination in the space, or do they only require some "bottom-line" summary metric? Software designed for the former requirement could most likely be easily modified to deliver summary metrics also. The reverse is unlikely to be true since the tool for the summary metrics was most likely designed to deliver these by the most straightforward procedural means. Thus the framework used is unlikely to be readily extensible in order to accommodate modelling modalities that were not originally envisaged by the tool designer.

Inevitably there is a strong trend in the formulation compliance guidelines of towards seemingly unambiguous summary metrics, often a single "target" value, e.g. the space achieves an average daylight factor of 2%. The rationale for this is twofold. Firstly, the quite reasonable belief that simple targets are likely to be both easy to compute and easy to understand. Secondly, the belief that the more complex the target the greater the chance for "game playing" in demonstrating compliance with it. There is much truth in both of these beliefs, however recent developments have demonstrated that some quite seemingly simple daylight targets are in fact quite challenging to predict. e.g. LEED daylight proposal. Long-standing simple targets such as achieving an average DF of 2% are also open to game playing and misinterpretation.

Even something as simple as specifying a sensor grid is not as straightforward as might seem at first, depending on the application. For example, a rectangular workplane can be easily converted to a grid of horizontal sensor points. But what if the evaluation also requires simulation of light that arrives at the eye for modelling non-visual effects and/or visual comfort, e.g. vertical illuminance or scene luminance? The eye will be at a vertical height ~40 cm above the workplane, and can, in principle, have any view direction though it will tend to be "across" the workplane. Given that workplanes can be arbitrary in shape, it is unlikely that an automated scheme could reliably locate the occupants' eye sensor point and typical view direction from just a horizontal workplane manual intervention would most likely be required.

Climate-based metrics

Climate-based daylight modelling (CDBM) is now established as the successor to the standard "snapshot" approaches such as the daylight factor. Climate-based modelling delivers predictions of absolute quantities (e.g. illuminance) that are dependent both on the locale (i.e. geographically-specific climate data is used) and the building orientation (i.e. the illumination effect of the sun and nonovercast sky conditions are included), in addition to the building's composition and configuration. Whilst the various underlying "engines" for CBDM are relatively wellestablished, having undergone varying degrees of validation, there is little consensus on the form that the metrics derived from predictions should take. For example, having generated an annual time-series for illuminance at, say, the work-plane, the overall provision needs to be assessed using one of the various metrics that have been proposed, e.g. Useful Daylight Illuminance -Mardaljevic and Nabil (2005), Daylight Autonomy - Reinhart et al. (2006).Acceptable Illuminance Extent - Kleindienst and Andersen (2012), amongst others.

Daylight illuminance on a horizontal plane for task is just one aspect of daylight provision. Additional phenomena / effects that we might wish to gain knowledge of at the design stage include:

- The potential to displace electric lighting.
- The propensity for visual discomfort.
- Some measure of the accessibility and the nature of the views to the outside.
- An indication of the potential for daylight to produce non-visual effects

(once associated models are better defined).

Thus, there are multiple daylight and daylight-related quantities that each require some measure which, in principle, could be predicted at the design stage for the purpose of evaluation and/or compliance testing. This abstract describes various approaches that have been devised to predict these quantities, giving examples in each case. The final presentation contains a discussion on the potential to integrate these approaches into a Necessarily, unified scheme. the practicalities with respect to the computation of each individual solution will figure in the discussion. The main thrust of the discussion however will be to determine what properties/dimensions of the (for most cases) inherently spatio-temporal nature of the various metrics need to be made available to the designer, and what form the presentation of data should take. For the end-user/client, the various outputs should be perceived as offering a holistic insight into the daylighting performance of the space, rather than as a series of plots with seemingly little relation to each other. Thus our notion of a 'unified framework' applies to both the practicalities of the input and the intelligibility of the output.

Spatial Properties of Daylight Provision

One metric used to evaluate daylighting provision - which correlates somewhat with the potential to displace electric lighting - is the "useful daylight illuminance" (UDI) scheme devised by Mardaljevic and Nabil (2005). Put simply, achieved UDI is defined as the annual occurrence of illuminances across the work plane that are within a range considered "useful" by occupants. Thus UDI is in part a human factors derived metric. The UDI scheme is applied by determining at each calculation point the occurrence of daylight levels where:

- The illuminance is less than 100 lux, i.e. UDI 'fell-short' (or UDI-f).
- The illuminance is greater than 100 lux and less than 300 lux, i.e. UDI supplementary (or UDI-s).



- The illuminance is greater than 300 lux and less than 3,000 lux, i.e. UDI autonomous (or UDI-a).
- The illuminance is greater than 3,000 lux, i.e. UDI exceeded (or UDI-e).

Daylight autonomy, another climate-based metric, is a measure of how often in the year a specified illuminance (e.g. 300 lux) is achieved. The daylight autonomy value for an illuminance of 300 lux is very similar to UDI-a. The main difference is that the UDI scheme includes the occurrence of exceedances of an upper illuminance limit, in this case 3,000 lux. Thus, the annual occurrence of UDI-a will generally be less than that for DA at 300 lux.

With UDI the user may be presented with four plots showing the annual occurrence in each of the UDI categories as a false-colour spatial map, Figure 1. Here the occurrence was determined between the hours 08h00 and 20h00. The space is a residential living room with a window on one side. Within reason, any number of sensor planes could be used to cover the room area - here there are nine. Each of the distinct sensor planes is annotated with the mean value for the occurrence across that plane. Thus the average occurrence of UDI-a (i.e. 300 to 3,000 lux) for the central sensor plane in the middle of the room was 1,764 hours. If a single value is needed to characterise the

space for each of the four categories, then an area weighted value for all the sensors is probably the most appropriate. In which case, the daylighting performance of the entire space could, in UDI herms, be characterised for just four numbers. Whilst UDI-e *may* be a proxy for the potential of visual discomfort, it is not yet known how robust or reliable the relation between the two might be.

Temporal Properties of Daylight Provision

To address the issue of data overload resulting from annual analyses, a novel goalbased metric, called Acceptable Illuminance Extent or AIE, reports the per cent of an area of interest that stays within a user-defined illuminance goal range (Kleindienst and Andersen, 2012); in other words, it defines the amount of space that stays within acceptable limits at any given moment in time and thus avoids any kind of Đ potentially misleading - averaging. It is conceptually similar to the UDI metric in that it applies a lower and an upper threshold, but fuzzy boundaries it has and, more importantly, it relates to a whole perimeter of interest.

Starting from illuminance goals driven by the design intent (e.g. derived from norms or regulations), AIE can be calculated as follows: given an array of illuminances over an area of interest (AOI), the number of

Fig 1: Example UDI



sensor points (or sensor patches in the case of radiosity-based calculations) that fall within the desired range is determined, as well as the number of sensors where illuminances were too high or too low. The per cent of total sensors that fall within the goal range is the AIE, illustrated in Figure 2.

To display this information in an intuitive and efficient way, the temporal map format is used that shows how much of any given area of interest falls within the desired range at any given moment in time, as illustrated in Figure 2. The colour scale was introduced in Kleindienst and Andersen (2012)to communicate information about goals exceedance, falling short and compliance in a single graph. The scale is triangular (Figure 2) where yellow represents data that have met the designer's goals, blue represents data that are too low, and red represents data that are too high. Following from this, purple, for example, represents a moment when the data include both high and low values, such as in a dim room with direct sun spots. Any colour within the triangle is thus a possible outcome.

Potential for non-visual effects

The daily cycle of day and night plays a major role in regulating and maintaining 24hour rhythms in many aspects of our physiology, metabolism and behaviour. The retina of the eye contains not only the wellknown photoreceptors which are used to detect light for vision (i.e. rod and cones) but also contain a subset of specialised retinal cells ganglion that are intrinsically photosensitive and project directly to brain areas mediating 'non-visual' responses to light. The timing, intensity, spectrum, duration, pattern of light received at the eye, and prior light history, are the principal factors determining entrainment of the circadian cycle. An attempt at combining intensity of light exposure at the eye with timing (and to some extent spectrum) into a condensed format has been proposed in the form of a 'sombrero' plot, reproduced in Figure 3, which "categorises" circadian entrainment in three periods of the day (represented as three concentric rings) based on their expected effects on our biological



Fig 3: The 'sombrero' plot

clock (Andersen et al., 2012). It thus offers a particularly synthetic visualisation of 'potential for non-visual effects' for a given location, and for four view directions. Its combination with temporal a map information can bring very valuable and intuitive input for design decisions, by quickly pointing out at potential light overor under-exposure depending on the time of day. For example, high values for late evening exposure (outer ring) should typically be avoided for a healthy dark-light cycles. The space used for this example was the same as that in Figure 1. However, the 16 potential occupant head positions were manually located rather than derived directly from the 9 workplanes.

Discussion

Is it possible to carry out these and other disparate evaluations within a 'unified modeling framework'? To be discussed in the full presentation.

Acknowledgements

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Prejudice in the Dark: How Darkness Facilitates Negative Associations with a Feared Out-group

A. M. Wennekers, R. W. Holland, D. H. J. Wigboldus, & A. Van Knippenberg

Behavioural Science Institute, Radboud University Nijmegen, the Netherlands

Introduction

Emotions play an important role in intergroup relations (Smith, 1993). Recent perspectives on prejudice emphasize that people may not only experience general negative affect toward people from other groups, but that specific negative emotions – such as fear, disgust, or anger – are associated with different out-groups (e.g., Cottrell & Neuberg, 2005; Fiske, Cuddy, Glick, & Xu, 2002; Mackie & Smith, 2002).

Experiencing these emotions outside a group context may also affect implicit forms of prejudice toward a group that is associated with the activated emotion (Dasgupta, DeSteno, Williams, & Hunsinger, 2009). People who recalled an event in which they experienced disgust showed stronger negative associations toward homosexuals (a group associated with disgust) on a subsequent implicit association measure, but not toward Arabs (a group associated with anger). Recalling an anger-related event resulted in the opposite pattern of findings.

An explanation for these findings may be that people (unconsciously) search for causes of their emotional experience, because the negative emotion could be a signal for a potential threat in the environment (e.g., disgust could signal a contamination threat, anger a threat for resources, fear a physical threat, see Cottrell & Neuberg, 2005). While looking for potential sources of this threat, the emotional experience may be misattributed to the group that is associated with that emotion and its related threat. Negative characteristics of the group become salient, which may strengthen the negative associations with the group (see Dasgupta et al., 2009).

Following this line of reasoning, a more subtle and ecologically valid signal of threat

should result in similar emotion-specific effects on implicit prejudice. In the present research, we focus on an environmental cue that is strongly associated with danger, i.e., darkness (Grillon, Pellowski, Merikangas, & Davis, 1997). Specifically, we study the effects of a dark environment on the negative associations toward a group that is primarily related with the experience of fear (i.e., Moroccan males for female participants, see Wennekers, Holland, Wigboldus, & Van Knippenberg, 2012). According to recent findings, out-group males are the primary targets of ethnic prejudice (Navarrete et al., 2009), and this prejudice is based on anger in males and fear in females (Navarrete, McDonald, Molina, & Sidanius, 2010).

A previous study on the relation between darkness and out-group bias showed that a dark environment strengthened the stereotypic association between African-Americans and danger, but only for people with a chronic belief that our world is a dangerous place (Schaller, Park, & Mueller, 2003). However, if darkness is a general signal for danger, negative associations toward a feared outgroup should be enhanced (cf., Dasgupta et al., 2009).

In summary, we expected darkness to affect implicit negative associations with Moroccans for female participants. In emotion-specificity accordance with findings, a negative cue that is not associated with danger (i.e., a bad smell) should not increase negative associations with Moroccans. In the same vein, darkness should not enhance negative associations with an out-group that is not associated with fear or danger (i.e., obese people).

We tested these hypotheses in two studies. In the first study, we manipulated the environment by turning off the light (darkness), or spreading a nasty odor (bad smell). In the control condition, the light was turned on and no odor was spread. Implicit associations toward Moroccans or obese people were measured using a Single-Target Implicit Association Test (ST-IAT; Wigboldus, Holland, & Van Knippenberg, 2004). In the second study, we focused only on the dark versus light manipulation, and measured implicit negative associations with Moroccans.

Study 1: Method and Results

Sixty-six female students of Radboud University Nijmegen participated in this study. They were randomly assigned to one of the 3 environmental cue conditions (darkness, bad smell, control). In the room with the environmental cue manipulation, they received two measures of implicit associations, one ST-IAT toward Moroccans and one ST-IAT toward obese people. The of order these measures was counterbalanced, but because of significant order effects of the two ST-IATs, we only analyzed the first ST-IAT, thus resulting in a between-subjects factor of type of ST-IAT (Moroccan versus obese people). The data of one participant from the bad smell condition were removed, because she reported a diminished smelling ability.

All participants started in a normally lit research room, where they completed a sequential priming task (Fazio, Sanbonmatsu, Powell, & Kardes, 1986, also known as Affective Priming Task; APT). In this task, they had to categorize pictures as being related to fear or disgust. These pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthberth, 1999). Preceding the emotion picture, a prime was presented depicting a picture from one of four categories: Moroccan males, obese people, homeless people, or students. The prime pictures were selected from the Amsterdam Dynamic Facial Expressions Set (ADFES; Van der Schalk, Hawk, Fischer, & Doosje, 2011), the Internet, and from a picture set by Degner and Wentura (2011).

After the APT, participants were led to one of two identical cubicles containing a desk and а computer. Here. the environmental cue was manipulated. In one of the cubicles, we spread a bad smell by putting two drops of liquid odor (provided by Smartnose) on a cotton pad hidden underneath the desk. In the other cubicle, the glass window above the door was covered with dark carton paper. By turning off the light, the cubicle became completely dark, aside from the light coming from the computer screen. By turning on the light, this cubicle was normally lit. In the cubicle, participants performed the implicit association measures toward Moroccans and obese people (ST-IATs). Besides the difference in target category, the tasks were identical.

In the ST-IATs, participants first had to categorize pictures as being positive or negative. In the second and third block, positive and negative pictures had to be categorized, as well as pictures of the target category (obese people or Moroccan males). In one of the blocks, the pictures of the target category had to be categorized using the same key as the negative pictures (i.e., the compatible block), whereas these pictures had to be categorized using the same key as the positive pictures in the other block (i.e., the incompatible block). Each block consisted of 40 trials, and the order of the blocks was counterbalanced. Note that the ST-IAT had a black background screen in all conditions to minimize the amount of light coming from the screen. Importantly, the negative pictures consisted of the fear and disgust pictures that were used in the APT. The target category pictures consisted of the Moroccan male pictures and obese people pictures from the APT, supplemented by 3 new pictures, from the Internet and Radboud Faces Database (Langner et al., 2010).

After having finished the ST-IAT, participants were brought back to the first research room where they filled out some demographics and questions about the study.

Incorrect trials on the ST-IATs were coded as missing values, as well as latencies faster than 300 ms and slower than 3000 ms.

The remaining latencies were logtransformed, but the untransformed latencies will be reported for sake of clarity. For each participant, the mean latency in the compatible block was subtracted from the mean latency in the incompatible block. Higher difference scores thus reflect more negative associations toward the target group.

These ST-IAT scores were subjected to a 3 (environmental cue: dark, bad smell, normal) X 2 (social category: obese versus Moroccan) between-subjects ANOVA, which revealed a significant interaction between these two factors, F(2,59) = 3.38, p = .041, η_p^2 = .103. Simple contrast analyses revealed a significant effect of environmental cue for the Moroccan ST-IAT (F(2, 59) =3.75, p = .029, $\eta_p^2 = .113$), but not for the obese people ST-IAT (F < 1, *n.s.*). As expected, ST-IAT scores toward Moroccan males were significantly higher in the dark condition (M = 108; SD = 73) as compared to the light condition (M = 38; SD = 36) or the bad smell condition (M = 23; SD = 48), respectively p = .043 and p = .010. However, the ST-IAT scores toward obese people did not differ significantly for the dark (M = 45;SD = 58), light (M = 51; SD = 69) or bad smell (M = 78; SD = 69) condition, all ps >.319. See *Figure 1* for an illustration.



Fig. 1: The means and 95% CI of ST-IAT scores, depicted for environmental cue and type of ST-IAT.

Study 2: Method and Results

Forty-seven female students of Radboud University Nijmegen were randomly assigned to one of 2 environmental cue conditions (darkness versus light).

Participants again started in a normally lit research room, where they performed an evaluative priming task similar to the one of Study 1, but now including only Moroccan males and Dutch males as primes. After the APT, participants were brought to a cubicle that was either normally lit or dark (manipulated in the same way as in Study 1). Here, they performed a ST-IAT toward Moroccans, following the same procedure as in Study 1. In addition, we now asked participants to indicate on a slider from 0 (not at all) to 100 (very much) to what extent they experienced certain feelings at that moment, in the following order: fearful (angstig), relaxed (ontspannen), nervous (nervous), uncomfortable (ongemakkelijk), and calm (rustig). We started with 'fearful, because we were primarily interested in testing whether darkness increased feelings of fear. Finally, participants were brought back to the first research room where they filled out some extra questions.

The ST-IAT scores were prepared in the same way as in Study 1 and subjected to an ANOVA, which revealed a significant main effect of environmental cue, F(1, 45) = 4.16, p = .047, $\eta_p^2 = .085$. We replicated the findings of Study 1, showing that the ST-IAT scores toward people of Moroccan descent were significantly higher in the dark condition (M = 71; SD = 63) as compared to the light condition (M = 30; SD = 50). Thus, darkness again led to more negative implicit associations toward Moroccans as compared to a normally lit control condition.

Analyses of participants' feelings in the cubicle only revealed a marginally significant effect for 'fearful', F(1, 45) = 3.13, p = .084, $\eta_p^2 = .065$, showing that people reported to be slightly more fearful in the dark cubicle (M = 20.41, SD = 21.80) as compared to the light cubicle (M = 11.00, SD = 14.30). On the other reported feelings, participants in the dark cubicle did not differ from participants in the light condition, all Fs < 1.01, *n.s.*

Discussion

In two studies, we show that darkness can temporarily strengthen negative associations with an out-group that is associated with fear. As expected, Study 1 suggests that the effects are not driven by mere negativity of the environmental cue, because negative associations toward a non-feared negative outgroup (obese people) were not affected by darkness, and non-fear related negative cue (a bad smell) did not enhance negative associations with Moroccans. The results of these studies fit nicely with previous effects of emotion recall on implicit prejudice (Dasgupta et al., 2009), but now using a subtle and ecologically valid threat cue.

Furthermore, the findings extend knowledge of effects of darkness on implicit out-group bias (Schaller, Park, & Mueller, 2003). Whereas this previous study found only an interaction effect between darkness and chronic beliefs about a dangerous world, we obtained a main effect of the darkness manipulation on implicit negative associations. However, other studies in the present research line suggest that our effects may be contingent upon the procedure in which we first prime fear and disgust pictures in the APT which then reappear in the ST-IAT. Possibly, darkness in itself is not a strong enough signal of threat (especially in a controlled laboratory environment), and our priming procedure enhances the associations between fear and Moroccans, which are then re-activated during the ST-IAT in the dark. Future research should shed more light on the processes underlying effects of darkness on implicit out-group bias.

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Poster

Luminance Environments and their Impact on Performance, Fatigue and Preferences

C. Hubschneider¹, J. de Boer², A. Steidle¹, L. Werth³, & K. Sedlbauer^{1,2}

¹ University of Stuttgart, Stuttgart, Germany ² Fraunhofer Institute for Building Physics IBP, Stuttgart, Germany ³ Chemnitz University of Technology, Chemnitz, Germany

Introduction

During the last decades, office lighting has changed profoundly. Today, displays are a central component of work space which is characterized as an additional component of the luminance environment. According to Loe, Mansfield and Rowlands (1994) the relevant part of the field of view for the room assessment consists of different areas. In a simplified model, we can identify the screen, the working desk, the background behind the screen and the window as relevant areas in office rooms. The aim of the current study was to investigate the combined influence of all these areas on human performance, fatigue and preferences.

Study design

Sixteen subjects (aged from 17 to 28) participated in the study. Six different lighting scenarios were simulated in a laboratory by using either an artificial window to simulate daylight or the artificial lighting. The scenarios differed in the horizontal illuminance on the working desk and in the luminance on the wall. Horizontal illuminances from 300lx to 1000lx and wall luminances from 50cd/m² to 220cd/m² were presented to the subjects.

Additionally three different monitor luminances were used: $90cd/m^2$, $140cd/m^2$ and $190cd/m^2$. The three different monitor settings were presented in the six different lighting situations. Taken together, the subjects passed eighteen different luminance environments with different levels and ratios of brightness.

According to Boyce (2004) there are three routes by which lighting influences the

human performance: the visual system, the circadian system and the perceptual system.

In order to measure the visual component of the human performance, two visual tasks were selected:

• numerical verification task

• transient adaption task

Furthermore the circadian route was considered. To investigate the influences of the lighting situations on this route, three measurements were chosen:

- Fatigue
- Alertness

• Concentration-performance test

The perceptual system as the third route was measured by:

- Mood
- Room perception
- Preferences

Analyzing the results

The results are currently analyzed in order to demonstrate how different luminance environments influence the participants' performance, fatigue and preferences. For example there should be different preferences for the monitor luminance depending on the lighting scenario and different degrees of fatigue depending on the luminance ratios in the field of view.

The current research will thus contribute to the following issues: Does the luminance environment or the luminance ratio in the field of view influence the subjects' performance, fatigue and preferences? These findings should be relevant for the formulation of future lighting standards and the creation of lighting control systems

Parts of the analysis of the results will be presented in the poster.

Poster

Lighting Objects and their Implications in Humans

A. De Anda González

UNAM, Mexico City Eindhoven University of Technology, Eindhoven, the Netherlands

Introduction

This poster is about in principle about lighting objects, but what we understand about this concept? We can define that are objects with light, but it could be the sun or the stars, or objects with artificial light, and we can think about the lamps and the fixtures. But, in this poster I focused on the study of some specific object of daily use that includes the light. To determine this specific objects, This study present a classification of different kind of lighting objects. This classification is based on the role of light in conjunction with the object. For example we have the lamps that emit artificial light, the fixtures, that are objects designed for the control and direction of the light, this two examples are objects to illuminate spaces, other objects use the light to develop a different function, for example the light inside the TV. are for watching images, if we don't have visible light into this objects they couldn't develop the function for it was created. Another different example it could be the light inside a refrigerator, in this case the light help us to interact with the food, but if we don't have a lamp into the refrigerator not be a problem, because the refrigerator not need the visible light to conserve the food. Another example it could be a computer or a cellphone, the interface have visible light, and if we don't have the interface we can't interact with the objects, in this case the function of the visible light are different and indispensable, But what happened if we have a chair or a table with light, in some cases the light are justified but in other they not play a principal function. So, the question is why the designers are designing these new applications? In some cases are because the characteristics of new lighting technologies

like LEDs permit that. But the questions is, if this new applications are beneficent or not for human's beings. This study focused in the last lighting objects examples. What are the effects on humans about the results of these interactions between the human and a table with light? Other justified or this application could be an emotional effect. And we know that, because of the studies about the effects of light in humans in different levels, psychological, biological, to mention ones. The study are focused in describe this lighting objects, determined the factors around their design, the interaction between the human and this objects and the results about this interactions, especially in areas about the emotion effects of light in human beings.



Fig. 1: Classification of objects with light

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Come Together! Light, Temperature, and Social Behavior

A. Steidle¹, L. Werth², E-V. Hanke², & P. Kolb²

¹ University of Stuttgart, Stuttgart, Germany ² Chemnitz University of Technology, Chemintz, Germany

Aspects of the physical environment fundamentally influence social perception and behavior by evoking bodily and perceptual experiences that signal social distance or proximity and can trigger compensatory behavior (Bargh & Shaley, 2012; IJzerman & Semin, 2009; Kolb, Gockel, & Werth, 2012; Williams & Bargh, 2008). However, most research focuses on a single ambient condition and thus neglects the interaction among them. The current study investigated the combined effects of light and temperature on social motivation, perception, and behavior. Based on previous findings indicating that darkness (Baron, Rea, & Daniels, 1992; Gergen, Gergen, & Barton, 1973; Miwa & Hanyu, 2006) and cold temperatures (IJzerman & Semin, 2009; Kolb, Gockel, & Werth, 2012) promote strivings for social proximity, we expected that people sitting in a cold, dim room would be particularly motivated to get into contact with other individuals, perceive them as more attractive, and show affiliative behavior.

One-hundred forty eight participants worked for 1.5 h in one of four ambient conditions differing in illuminance (150 vs. 1500 lux) and room temperature (20 vs. 26° C). During 30 minutes adaptation time, participants answered various personality questionnaires (e.g., trait affiliation, trait loneliness, BIG5). Afterwards, participants assessed their current social motivation: perceived loneliness and openness for contact (adapted from Nitsch, 1976), hope for affiliation and fear of rejection (Multi-Motive Grid, Schmalt, Sokolowski, & Langens, 2000). Participants then saw four fictive Facebook profiles and rated the owner's warmth and competence. Finally, participants were asked to imagine going abroad and having a fellow student who would help them during the first days. Participants then had the possibility to write a Facebook message to the fellow student. The length of the message measured participants' self disclosure (Miwa & Hanyu, 2006).

We controlled for trait affiliation, trait loneliness, age, and gender in all analyses. As expected, illuminance and temperature influenced participants' social motivation. Participants in the dim room reported less fear for rejection than participants in the brightly lit room, F(1, 139) = 4.27, p = .046, η_p^2 = .03. Additionally, participants in the cold room felt more lonely and were more open to contact than participants in the warm room, Fs(1, 139) > 5.11, p < .025, $\eta_p^2 > .04$. Feeling lonely without fear of rejection, participants in the dim and cold room rated the fictive Facebook users more positively (competent and warm) than participants in the other conditions, F(4, 131) = 2.61, p =.038, η_p^2 = .07. This suggests that participants in the dim and cold room are most interested in getting into contact with others individuals. In contrast, not feeling lonely and fearing rejection, participants in the bright and warm room wrote significantly shorter messages to their fellow students than those in the other conditions, F(1, 139) =4.54, p = .035, $\eta_p^2 = .03$.

This study demonstrates that both light and temperature influence strivings for social proximity. Specifically, a cold, dim room triggers motivation to get into contact and promotes a positive evaluation of other individuals, whereas the combination of bright light and warmth reduced participants' self-disclosure. Overall, the current study is in line with the notion of embodiment and grounded cognition (Barsalou, 2008) and points out the importance of investigating the combined effects of ambient conditions.

Light Preference and Mood in Extreme Chronotypes in Response to Different Office Lighting Conditions: Preliminary Results

A. Borisuit¹, L. Maierova^{1,2}, J-L. Scartezzini¹, & M. Münch¹

 ¹ Solar Energy and Building Physics Laboratory, École Polytechnique Fédérale de Lausanne, Switzerland
² Department of Microenvironmental and Building Services Engineering, Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic

Introduction

Most people spend more than eight hours at working places and certain office lighting conditions may not be optimal for everybody. Thus, it becomes crucial to also take interindividual differences into account. This study aimed to test the lighting preference under different lighting conditions and their impact on mood.

Methods

Based on diurnal sleep-wake preferences and as assessed by validated questionnaires, we only considered healthy young extreme chronotypes for the study. So far, eleven young morning types (MT) and seven evening types (ET) completed the study. The subjects came three times to the laboratory and spent sixteen hours under different lighting conditions. The three lighting conditions were 1) dim light (DIM; <5lux) condition; 2) bright light condition (BL; target vertical illuminance ≈ 1000 lux), and 3) a self-selected lighting (SSL) condition. The BL and SSL condition comprised both day- and artificial light. Each study session started approximately one hour after habitual wake time. Participants were asked to regularly rate their light preference and mood on different questionnaires (every 30-60 min).

Results

Overall, subjects assessed significantly higher light preference under SSL than both, BL and DIM conditions (3-way rANOVA; main effect of 'condition'; p<0.05). For BL, ET assessed significantly higher light preference during the first eight hours of the study than in the second half (p<0.05; Wilcoxon matched pairs test). MT assessed similar light preference at the beginning and the end of the study (p>0.6). For BL, greater light preference was associated with higher correlated colour temperature (CCT; r=0.28; p<0.05). For the SSL condition, greater light preference was significantly related to higher CCT (r=0.15; p<0.05), and higher vertical illuminance at the eye level (r=0.19; p<0.05).

In the DIM condition, mood became worse at the end of the study session for both chronotypes (1-way rANOVA; main effect of 'time'; p<0.05). This was not the case during the BL and the SSL condition, such that light prevented the decline of mood at the end of the study (p<0.05). Better mood was correlated with a higher CCT for both light conditions (BL: r=0.18; SSL: r=0.25; p<0.05).

Conclusion

Our preliminary results suggest differences in lighting preference between extreme chronotypes, which may reflect the effects of light exposure at different (internal) circadian phases. Whether light exerts also inter-individual effects on mood and other subjective and objective variables, needs to be analyzed with more subjects.

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The Impact of Different Lighting Conditions on Extreme Chronotypes: Effects on Physical Comfort and Alertness

L. Maierova^{1,2}, A. Borisuit¹, J-L. Scartezzini¹, & M. Münch¹

¹ Solar Energy and Building Physics Laboratory, École Polytechnique Fédérale de Lausanne, Switzerland ² Department of Microenvironmental and Building Services Engineering, Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic

Introduction

There is increasing knowledge of nonimage forming aspects of light which proves the importance of proper lighting on our wellbeing. Early studies investigating user preferences indicated similar results for the majority of subjects, but differences for subjects with extreme sleep-wake rhythms, known as early birds/late owls¹. We used these extreme chronotypes² as a 'natural model' to investigate circadian and acute effects of different lighting conditions on well-being, alertness, skin temperature and hormonal secretion.

Objectives

We aimed at testing visual and non-visual effects of three different lighting conditions in extreme chronotypes. We hypothesized that differences in timing, quality and intensity of lighting conditions might differently impact objective and subjective variables of physiology, well-being and alertness.

Subjects and Methods

Healthy young morning types (MT) and evening types (ET) were selected. All underwent three sessions with different lighting conditions: dim light (DIM; <5 lx); constant bright light (BL; ≈ 1000 lx in a vertical direction at the corneal level), and self-selected light (SSL). Each session lasted for 16 hours and began one hour after habitual time. Ouestionnaires, wake cognitive performance tests, hormonal analyses and skin temperature measurements were used. So far, 18 subjects (11 MT and 7 ET) completed the study.

Results

Preliminary results from questionnaires suggest that subjects felt significantly more alert under the BL and SSL condition, when compared to DIM (2-way rANOVA; main effect of 'condition'; p<0.05). During the BL condition, MT felt significantly more alert during the first half of the study session than the second half (p<0.05; Wilcoxon matched pairs test).

Subjective wellbeing decreased over time for both chronotypes (p<0.05; main effect of time) such that MT felt less well in the second half of the SSL condition, whereas ET felt less well in the second half of the BL condition (p<0.05; Wilcoxon matched pairs test).

Subjective thermal assessments revealed that subjects felt significantly colder throughout the DIM condition, when compared to BL and SSL (p<0.05; main effect of 'condition').

Conclusions

A better knowledge of inter-individual acute and circadian light effects could contribute to develop high quality indoor lighting environments which also consider physiological and behavioral needs.

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Nonvisual Light-Response Model: A Preliminary Approach to Integrating Recent Findings in Biology into a Lighting Simulation Process

M. L. Ámundadóttir¹, M. Andersen¹, & S.W. Lockley²

 ¹ Interdisciplinary Laboratory of Performance-Integrated Design (LIPID), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
² Division of Sleep Medicine, Department of Medicine, Brigham and Women's Hospital Harvard Medical School, Boston, MA, USA

Introduction

visual In addition to stimulating responses, light induces a range of circadian, neuroendocrine and neurobehavioral nonvisual responses in humans. These effects are mediated primarily via a novel non-rod, noncone photoreceptor, which is most sensitive to blue light (λ_{max} 480nm) and exhibits different sensitivity to the spectrum, timing, intensity, duration and pattern of exposure as compared to visual responses. The discovery of this novel photoreceptor has led to consideration of the nonvisual effects of light as an important element of healthy lighting design in addition to vision. Before application of these new findings, however, it is necessary to first understand, and then model how the nonvisual system responds to light. One challenging aspect is the fact that the nonvisual system adapts its responses to changes in light intensity and spectral composition over a much longer timeframe than the visual system. Here, we propose a functional model of the nonvisual lightresponse relationship that combines temporal integration and a static nonlinear function.

Approach

We apply a commonly used system approach to describe human processing of nonvisual light. In the model the light stimulus l(t) is passed through a linear filter $L_1(t)$ giving the output u(t). Then u(t) is transformed by a static nonlinear function N(u) describing the intensity-response relationship to the light stimulus. The output of N(u), v(t), is then passed through a second filter $L_2(t)$. Thus, the two linear filters reflect the temporal processing between the light stimulus and the output response. Preliminary results show that the model can capture the nonvisual response of timevarying light exposure, but it is limited to bright light intensities due to lack of experimental data. However, the model is not limited to one type of intensity-response function, which allows for more flexibility as knowledge accumulates.

Application

Linking the model to a lighting simulation process is important, because the ultimate goal is to develop a new type of lighting design support. In the interest of providing the designer with an informative visual representation, an additional user-defined input is required specific to the desired design performance. By evaluating the response output against such user-defined goals, a format can be provided to the designer illustrating whether a given goal is met or not.



Fig. 1: A diagram of the light-response model structure and its linkage. This type of functional model is referred to as linear-nonlinear-linear (LNL) model.

Conclusion

The light-response model holds promise because it aims to understand and functionally describe the underlying mechanism of the nonvisual system. Moreover, it may lead to a new approach to support healthy lighting design, but further research has to be conducted to refine and validate the proposed model.

Effects of Daylight and Artificial Light on Melatonin Suppression in Educational Environment

L. Bellia¹, G. Barbato², & A. Pedace¹

¹ DETEC, University of Naples Federico II, Italy ² Department of Psychology, SUN, Italy

Introduction

Daylight in indoor environments allows to achieve reductions of energy consumption [1], but it is even more important for its effects on human beings in terms of visual comfort and impact on circadian rhythm regulation [2]. Therefore it results necessary to evaluate the entrance of natural light in indoor environments both in qualitative and quantitative terms.

An analysis of the characteristics of daylight in an indoor environment is presented here, it was carried out by comparing SPDs and CCTs of the natural source (sky) during typical days with contemporaneous measurements of spectral irradiances and CCTs detected at the eyes level. Data obtained from these measurements together with those detected with artificial light, were used to evaluate the effects on melatonin suppression during the day according to the procedure proposed by Rea et al [2].

Description of measures

different Measurements with sky conditions (clear and overcast) during winter days were carried out in a representative classroom with western windows, located at the 6th floor of the Federico II University, Faculty of Architecture. Data were acquired from morning until twilight at one hour intervals. SPDs and CCTs of sky light, illuminances and spectral irradiances at eye's level were collected. Illuminances and spectral irradiances at eye were also acquired with the artificial light on. All spectral data were obtained by means of a Spectroradiometer Minolta CS-2000.

Results and discussion

Figures 1 and 2 show melatonin suppression in presence of daylight during typical clear and overcast winter days.







Fig. 2: Melatonin suppression during an overcast day

Although illuminances on desks under natural and artificial light corresponded to the EN 12464-1 Standard requirements, the irradiances detected at eye's level, which are essential for melatonin suppression, do not appear to always guarantee the necessary circadian stimulus. Hence much care should be devoted in designing lighting systems in educational environments in order to take into account their effects on the human circadian system regulation.

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Daylight to fulfill Lighting Needs for Demented Elderly

I. M. Nugteren¹, M. P. J. Aarts¹, & A. M. C. Schoutens²

¹ Eindhoven University of Technology, Eindhoven, the Netherlands ² Davita, Tilburg, the Netherlands

Introduction

A lighting design, attuned to visual and non-image forming (NIF) effects, contributes to the well being of elderly people with literature¹ Based dementia. on recommendations are found for illuminance levels (E) and color temperature (CCT). Visual and NIF effects can be achieved by electric lighting as well as by daylight. The aim of this study was to locate the position in the communal living room of a newly build Dutch nursing home, which fulfill both needs most of the time, using only daylight. The time slots for the NIF effects were taken from 10-11 am and from 3- 4 pm and for visual needs between 9 am and 5pm.

Methodology

To predict the illuminance levels, a model of the future situation was made, using the software program Radiance. Radiance models were made of the living rooms in their final state. To predict the illuminance levels over a whole year, the rtcontrib-tool [1] in Radiance was used. Color temperature measurements were performed in one of the living rooms under different sky conditions and different parts of the days. The software program DIALux was used to calculate the illuminance of the electrical lighting.

Results & discussion

Based on the simulation of the daylight *illuminance* levels, the extent to which the NIF needs (> 1000lx, vertical at eye) can be fulfilled strongly dependent on the position in the room, viewing angle, time of the day, and moment of the year. The illuminance levels near the window satisfy those needs most of the time when looking in the direction of the window (70 -100 % of the time between 10-11 am (figure 1) and 60-90

% between 3-4 pm). When looking away from the window, 4-70% of the time values over 1000 lx can be reached. The visual needs can be fulfilled between 30 and 95% of the time.



Figure 1% of the time (10-11 am) NIF effects are reached, looking at window

The kitchen and the back of the living rooms need additional lighting in more than 40% of the time for both lighting requirements. Based on the *CCT*-measurements, daylight can be used to fulfill the NIF needs for all measurement positions (measured values between 4700K - 6200K). Note that since the finishing of the room influences the CCT, the outcome might be different in the final situation.

Conclusion

Depending on the layout and finishing of the room, daylight can very well be used to fulfill both visual and NIF effects in communal living rooms for the largest part of the day. Additional lighting is needed to ensure the recommended lighting condition for 100% of the time.

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