Fact or fiction? : testing effects of suggested illuminance changes

Fact or Fiction? Testing Effects of Suggested Illuminance Changes

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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 work-related 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 cognitive task performance (Cajochen, 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 mood-related pathways also referred to as non-visual 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 design and theory, 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 offered different lighting scenarios, 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 1.5-minute 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 participants were 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 30-second 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 (ostensibly increasing) or 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, 1-minute 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

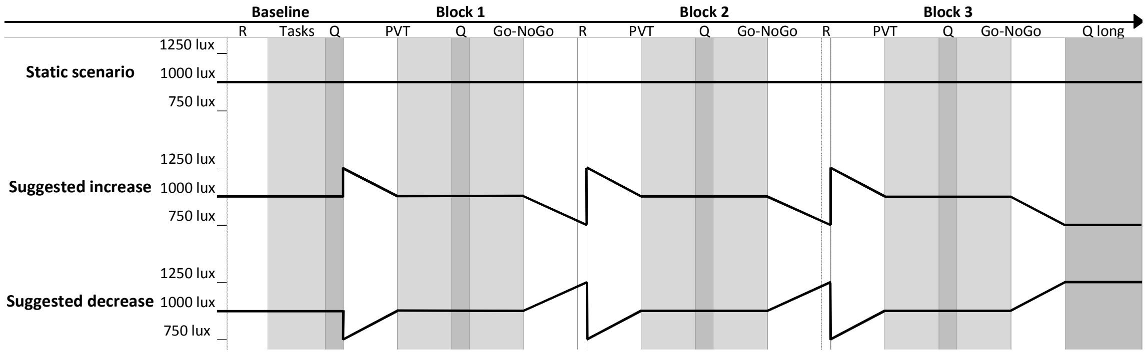

Fig. 1: Lighting scenarios of the three conditions. The three black lines indicate the illuminance level during the control (upper), ostensibly increasing (middle) and ostensibly decreasing (lower) conditions, R = rest period and Q = questionnaire, [grey box] = measurement task performance.

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.

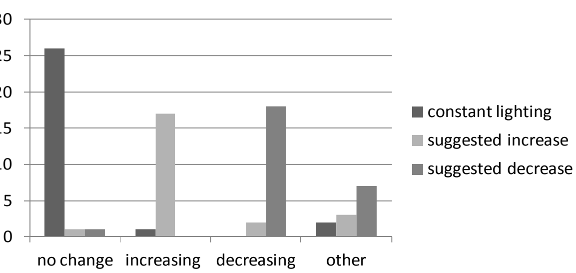

Fig. 2: Perceived changes in brightness.

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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