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The effect of variable light on the fidgetiness and social behavior of pupils in school

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ABSTRACT

Studies on the effects of light in work environments show that specific lighting situations have different effects on human performance and social behavior. These findings suggest that beneficial lighting should also be applied in schools. The aim of the present study was to examine the effect of variable lighting on pupils' fidgetiness and their aggressive and prosocial behaviors. The variable lighting system employed was equipped with seven lighting programs featuring different varieties of illuminance and color temperature. In a controlled, quasi-experimental field study, a combination of cross-sectional and longitudinal observations was collected. The participants included $n = 110$ pupils of various age levels and school types and $n = 11$ teachers from Hamburg. Fidgetiness was measured by the changes in pixel scores in a digital recording of the students. To quantify aggressiveness and prosocial behaviors, structured behavioral observations were conducted. Self-perceived changes throughout the school year were captured using questionnaires. The findings showed a significantly stronger decline in fidgetiness and observed aggressive behaviors and a tendency toward increased prosocial behaviors within the intervention group. In the long term, the pupils did not rate themselves as being calmer or less aggressive. Overall, the findings indicated that variable light could directly reduce pupils' restlessness and improve their social behaviors. Variable lighting can thus play a part in optimizing general conditions for school learning.

1. Introduction

Every day, we all encounter the effect of light on our experiences and behaviors. For example, everyone recognizes the activating effects and the positive mood generated by light on sunny summer days. Warm, dimmed lighting, however, seems to have a calming effect, as is the case with sunsets, fireplace fires and candlelight, for example. This effect suggests that interior lightning should be designed to adapt to the particular needs of human beings. This approach to lighting, called variable light (VL), is evaluated here. With VL, the brightness and color impression of light can be systematically changed. Consequently, interior lighting can be adjusted to meet specific demands. Despite the various forms of instruction found in schools (for example, silent work, group work and lectures) and their differing demands on pupils, classrooms currently have only a single, static lighting situation. While several studies have demonstrated the effectiveness of different lighting situations in work environments, few such studies have taken place in schools.

Light that is visible to the human eye is electromagnetic radiation with a wavelength of approximately 380–780 nm.

In terms of human perception, two of the most important features of light are illuminance and color temperature. Illuminance measured over a certain area is given as the luminous flux per square meter, which is measured in lux (lx). Color temperature equals the thermal temperature which an idealized black body would need to assume in order to produce the same color experience as the designated lamp. Color temperature is measured in degrees Kelvin (K). As far as the fluorescent lamps used in this study are concerned, the term "correlated color temperature" (CCT) is applied, because they are not blackbody radiators. Low color temperatures appear as warm color impressions (red, yellow), and high color temperatures appear as cold colors (white, blue; Rea, 2000). In the retina, light hits the retinal cones responsible for the perception of color and the retinal rods responsible for the perception of brightness; these impressions are then transmitted

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through the ganglion cells and through the optical nerve to reach the visual center in the occipital lobe, where a visual impression emerges (Pinel, 2010). An increase in illuminance results in an improvement in visual perception by means of increased brightness and color contrasts (Goldstein, 2002), which can in turn counteract visual impairments to some degree (Van Bommel, van den Beld & Fassian, 2004). In addition, increased illuminance can also alleviate signs of fatigue as well as eye pain and headaches (Goldstein, 2002; Van Bommel et al., 2004). The precise connection between light and immediate changes in an individual's experiences and behaviors has not yet been conclusively explained.

Studies on the effects of light on motor restlessness could not be obtained. Empirical studies indicate an improvement in communication and an increase in prosocial behaviors as a result of using warm, dimmed lighting in work environments. Participants at an office in a study performed by Fleischer (2001) preferred such lighting for discussions at a table and for more lengthy telephone calls. Participants in a simulated office setting were more likely to say they would respond co-operatively to a hypothetical conflict situation, and were more likely to volunteer in helping the experimenter, if they were exposed in the warm-white (3000 K) than in the cool-white (4200 K) condition (Baron, Rea, & Daniels, 1992). Additionally, the job applications of imaginary employees were assessed more positively in terms of their professional abilities and performance when the applications were reviewed in warm, dimmed lighting (Baron et al., 1992; Knez & Enmarker, 1998). However, in a study by Küller and Lindsten that included pupils in conditions of warm light at low illuminance, only a tendency toward improved communication and social behavior was observed (Küller & Lindsten, 1992). The extent to which social behavior improvements observed in office work environments may be transferable to students in school settings remains unclear because of differences in the target population, the setting and the tasks involved. Studies using blue-enriched light in office settings (Mills, Tomkins, & Schlangen, 2007; Viola, James, Schlangen, & Dijk, 2008) show, however, results thoroughly comparable with those in school settings with respect to attention and concentration (Barkmann, Wessolowski, & Schulte-Markwort, 2012; Sleegers et al., 2013). Further fields of application for VL are offices, industrial workplaces or retirement homes (licht.de, 2014). For example, first results of studies conducted in retirement homes show an improvement in communication and an increase in activity among the seniors (Sust, Dehoff, Lang, & Lorenz, 2012).

Accordingly, the aim of the current study was to examine the short- and long-term effects of VL on fidgetiness and social behavior in schools. The following research questions were posed:

1a) Are pupils in individual work sessions less fidgety when exposed to light with the warmest possible color temperature and low illuminance?
1b) Do aggressive behaviors during competition in work groups decrease given an appropriate light exposure?
1c) Do prosocial behaviors increase during such group work?
2a) Do pupils rate themselves as less fidgety over the course of the school year?
2b) Do pupils rate themselves as less aggressive over the course of the school year?

2. Methods

2.1. Design

In a cooperative project involving the Hamburg education authority, Philips Lighting and the University Medical Center Hamburg-Eppendorf, an initial investigation of the effectiveness of VL in a school setting was conducted. To study VL's effectiveness under real-life conditions, a controlled field study with a quasi-experimental group design was chosen. Over a period of nine months in two different schools, observations were made in one intact classroom in each school that served as the intervention groups and another parallel classroom in each school that served as the control groups. Two different design strategies were combined:

The effectiveness of the individual VL programs was recorded at monthly intervals using standardized test modules. The controlled execution of the test modules was undertaken by an external investigator. In the test module described here involving the impact of VL on social behaviors, the intervention and control classes were first tested using standard lighting (see description of VL settings below). Four weeks later, the test was readministered while the intervention classes were using the "Relax" lighting program and the control classes were using standard lighting.

(1) The overall effect of the free application of VL in regular daily instruction lessons was captured using standardized pre-post surveys with pupils and teachers at the beginning and end of the project. Decisions concerning light exposure during regular daily instruction lessons (without test modules: see above) were left up to the teacher and were recorded in the protocols. The pupils spent most of the school day either in the two VL classrooms or in the two control rooms. As is usually the case in Germany, the pupils remained in their assigned classroom and the teachers switched between rooms to teach different subjects.

Data from both established and study-specific questionnaires, performance tests and physical measurements were compiled, and these were supplemented with data from the students' files. The pupils and teachers were available as information sources.

2.2. Independent variable

"Schoolvision" is a form of VL especially designed by Philips for school use. It offers lighting programs adapted to different work and social arrangements used in schools. The teacher selects a program from the various preset lighting programs that is appropriate for the whole class. VL was implemented in the study classrooms by installing two light strips with five built-in Savio illuminators, each equipped with light-color modification implements (equipment: 2x TL5-54W/452 Activiva Active, 17,000 K, color rendering index CRI = 82; 1x TL5-54W/827, 2700 K, and CRI = 85), two non-color modifiable black/whiteboard lamps from the Arano family (equipment: 1x TL5-49W/840, 4000 K, and CRI = 85), and one wall-mounted operations console (system MultiDim DCMD125 and DCMD200S) per classroom in the intervention group.

The seven VL lighting programs implemented were chosen based on current research and in coordination with lighting experts and the participating schools:

1. "Standard" (300 lx, 4000 K): Geared to existing conventional lighting, corresponding to the norm DIN EN 12665 (DIN, 2006).
2. "Focus on the board": Bright illumination of the black/whiteboard surface (1000 lx, 4000 K) and dimmed illumination of the classroom (300 lx, 3800 K).
3. "Board only": A variant of Program 2 in which only the black/whiteboard is illuminated and the classroom lighting is completely switched off.
4. "Concentrate" (1060 lx, 5800 K): Very bright, daylight-white light for individual work, that demands a high degree of attention/concentration.