Classroom performance and academic achievement: Effects of light conditions and room temperature on the performance of cognitive tasks

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Classroom performance: Effects of light and room temperature

Abstract

Research concerning conditions that improve academic achievement is important because it has the potential to impact students' school experience and the standards of the education system. Improved conditions could seriously impact graduation rates and assessment scores across the entire education system. This study investigates the effects of room temperature, illuminance, and bulb type on cognitive performance. It is hypothesized that optimal cognitive performance will occur at 68°F, under bright, full-spectrum fluorescent lights with UV supplements. The sample is composed of 240 college students, and participants are matched in a between subjects factorial design. Expected findings show that all three independent variables have main effects and combine to create a synergetic interaction. Temperature is also found to have varied effects across tasks.

Classroom performance and academic achievement: Effects of light conditions and room temperature on the performance of cognitive tasks

Light and temperature conditions have serious potential to impact long-term academic achievement. As Hathaway (2001) found in his study on the effect of lighting on physical development and school performance, the type of light that is emitted from lamp bulbs can either accelerate a student's academic achievement or significantly delay it. One type of bulb used in the study, high-pressure sodium vapor lamps, delayed students slightly more than four months over the two-year study (Hathaway, 2001, p. 237).

The majority of research has been conducted longitudinally to assess the long-term effects of light conditions and room temperature. This proposed study, however, will assess the short-term effects by having participants come into the lab for a short duration of roughly half an hour. The duration of each conducted experiment will allow participants to become adequately accustomed to the conditions of the room, but will not be so lengthy that fatigue and boredom have an impact on results. Results from this study concerning the variables' short-term effects will apply directly to testing. Standardized test scores determine which schools get funding, which teachers get promoted, and even decide if students will proceed to the next grade or graduate in some cases. If room conditions have short-term effects on cognitive performance, then these effects can have an incredible impact on testing and the decisions that result from testing outcomes. It is important to know which room conditions are most beneficial in order to improve education outcomes as a whole.

The study conducted by Hathaway (2001) found that the highest academic achievement occurred in settings with full-spectrum fluorescent lights with UV supplements. The study was conducted over a two-year time span at five different sites. The five sites each used a specific bulb type throughout the duration of the experiment. Theories about causation cannot be drawn

from the study, however, because subjects could not be randomly assigned or matched. The differences between groups on socioeconomic status and attendance may have confounded the results.

A study by Hygge and Knez (2001) found that high illuminance improved some cognitive skills, including long-term recall and free recall. High illuminance was beneficial in both warmer afternoons and in cooler mornings. In fact, it improved cognitive performance in all conditions, regardless of temperature and time of day.

In a study conducted by Wargocki and Wyon (2011), when temperatures were decreased from 77°F to 68°F, performance on two numerical tasks and two language-based tasks improved significantly. However, only the speed of tasks improved, not the percentage of errors.

One prediction of this study is that room conditions will not have a uniform effect on each cognitive task. It is predicted that moderate heat stress will increase scores on the attention task, but decrease scores on the reading comprehension and problem-solving tasks. According to Wyon, Anderson, and Lundqvist (1979), warmer temperatures produce better performance for memory and tasks involving attention, while tasks demanding concentration are performed best in cooler temperatures.

The hypothesis of this study is that the three variables will have a synergetic interaction. It is hypothesized that optimal cognitive performance will occur in cooler room conditions, specifically at 68°F, under bright, full-spectrum fluorescent lights with UV supplements. Main effects of illuminance, room temperature, and bulb type are also predicted.

Method

Participants

A sample of 240 college students would be ideal, as ten subjects could be assigned to each condition. The sample could be drawn from the general Tulane University population.

Because the study is researching basic cognitive processes under conditions that apply to all people, the results would be generalizable to other populations.

Procedures

The study employs a 2 x 3 x 4 factorial between-subject design with three independent variables: Illuminance (dim; 300 lx and bright; 1500 lx), Bulb Type (cool-white fluorescent, full-spectrum fluorescent, and full-spectrum fluorescent with UV supplements), and Room Temperature (64, 68, 72, and 76°F). The illuminance levels are varied by muting tubes for the dim condition and muting none in the bright condition. Illuminance levels are measured on subjects' tables by a Hagner Luxmeter (Model E2). Bulbs are also changed depending on the condition in order to alter the type of light that is emitted. Room temperature is controlled by a computerized climate system.

Subjects are matched on gender, grade point average, time of day when study is administered, and scores on college-entry standardized tests. Participants are placed in one of the 24 conditions and are not told the true purpose of the study. Rather, they are told that the study is aiming to assess cognitive abilities, and it is not until debriefing that researchers reveal that the purpose of the study is to research how light conditions and room temperature affect performance on cognitive tasks. The use of deception is necessary because participants may attempt to be good subjects and alter their behavior to align with guessed hypotheses. Each participant will perform three tasks: (1) memory load search task, (2) reading comprehension, and (3) embedded figure task (EFT). Tasks should be administered individually and within a time frame that does not permit participants to complete each task. Through allowing participants a less than ample time frame to complete tasks, the researcher can assess speed.

Measures

Memory load search task. This task involves "searching through lines of 59 random

capital letters for five target letters defined at the beginning of each line" (Hygge & Knez, 2001, p. 293). There are five pages with 66 lines on each. Participants are scored on accuracy and speed. This task is designed to measure attention. High scores on accuracy indicate more errors and less accuracy, while high scores on speed indicate that more letters were completed in the allotted time and faster speed.

Reading Comprehension. Participants read text with choice points inserted, and they must choose one of three different words. All three words make immediate sense within the sentence, but only one word is correct within the context of the entire text (Wargocki & Wyon, 2011). This task is designed to measure reading comprehension. High scores indicate more errors and less accuracy.

Embedded Figure Task (EFT). This task "involves the subject being shown a complex design and then a simple shape. The subject is asked to find the simple shape in its embedded form within the complex shape" (Ring et al., 1999, p. 1306) (Fig. 1). This task is designed to measure problem-solving capabilities. High scores indicate the identification of more embedded figures.

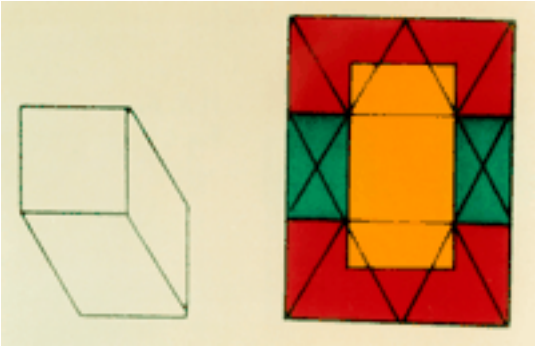

Fig. 1 The Embedded Figure Task. Example of a simple target shape and the complex figure containing it (Ring et al., 1999, p. 1306).

Cognitive Performance. Since the three dependent variables measure the same construct, they can me combined into a single measure. First, the three dependent variables'

scores are put on the same scale, and then the mean is computed. High scores indicate high cognitive performance, and low scores indicate low cognitive performance.

Anticipated Results and Discussion

A 3-way ANOVA is used to analyze results. The hypotheses concern the main effects, and also the interactions to determine if they are synergetic. Cohen's d tests are conducted between levels of each independent variable to determine the size of main effects. Cohen's d tests are also conducted between the 3-way interaction and the 2-way interactions to determine if the interaction between the three independent variables is synergetic and to determine how large the 3-way interaction is. A Cohen's d test is also conducted between the three dependent variables that measure attention, reading comprehension, and problem-solving capabilities to determine if warm temperatures have a distinctly different effect on attention scores than on reading comprehension and problem-solving scores. The expected findings are that optimal cognitive performance will occur at 68°F under bright, full-spectrum fluorescent lights with UV supplements due to a synergetic interaction among the three independent variables. It is also expected that illuminance, room temperature, and bulb type have main effects (Fig. 2, Fig. 3, & Fig. 4), and temperature has varied effects on the scores of the three different tasks (Fig. 5).

If the results of this study hold true, then school codes concerning environment need to encompass and enforce standards for illuminance, room temperature, and bulb type. The results of this study are especially important for high-stakes testing since this study focuses on the short-term effects of room conditions on cognitive performance. If it is shown that students perform significantly better or worse depending on room conditions, then high-stakes testing should not be administered when standard room conditions are not met. Also, if it is shown that warm temperatures improve performance on attention tasks and cool temperatures improve

performance on reading comprehension and problem-solving tasks, then lessons that require attention should be given in the afternoon when temperatures have risen and tasks that require concentration should be given in the morning when temperatures are cooler.

However, if the results of this study do not hold true, then future research is needed to clarify which environmental conditions foster optimal cognitive performance. Future research should investigate the effects of other environmental variables, including noise, air supply rate, and time of day.

Potential validity concerns of this study are individuals' light preferences, mood, and the absence of data on participants' external behavior. When participants' lighting preferences for either dim or bright light are matched, higher cognitive performance is predicted (Dunn, Krimsky, Murray & Quinn, 1985). However, poorer students have a tendency to prefer dim light (Dunn, Krimsky, Murray & Quinn, 1985). This research also neglects to observe behavior to see if participants are agitated by room conditions, and this would provide information pertaining to participants' mood (Wargocki & Wyon, 2011). According to research that supports the mood congruence theory, participants' mood is shown to have an impact on cognitive performance (Knez, 1995).

Fig. 2 2-way interaction between temperature and bulb type with two main effects.

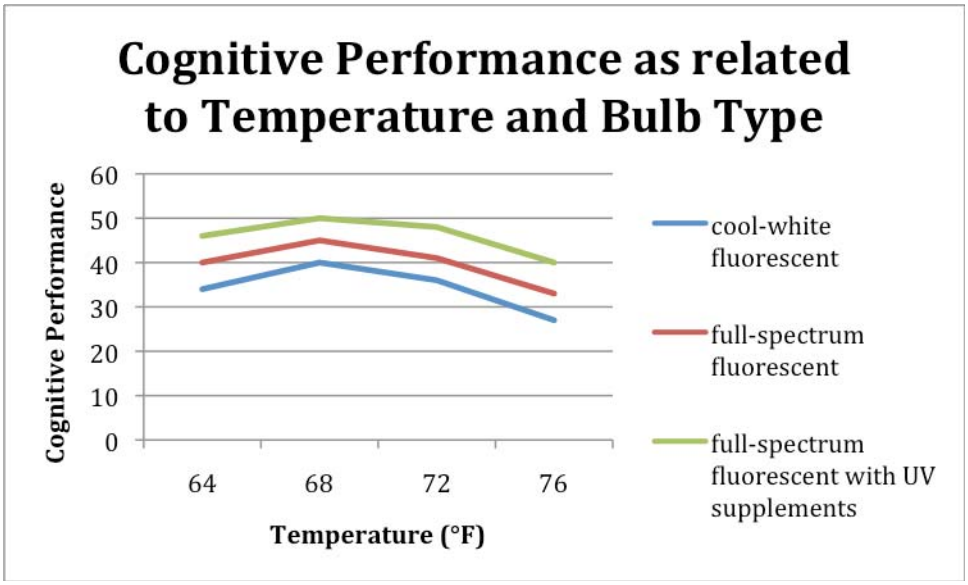

Fig. 3 2-way interaction between temperature and illuminance with two main effects.

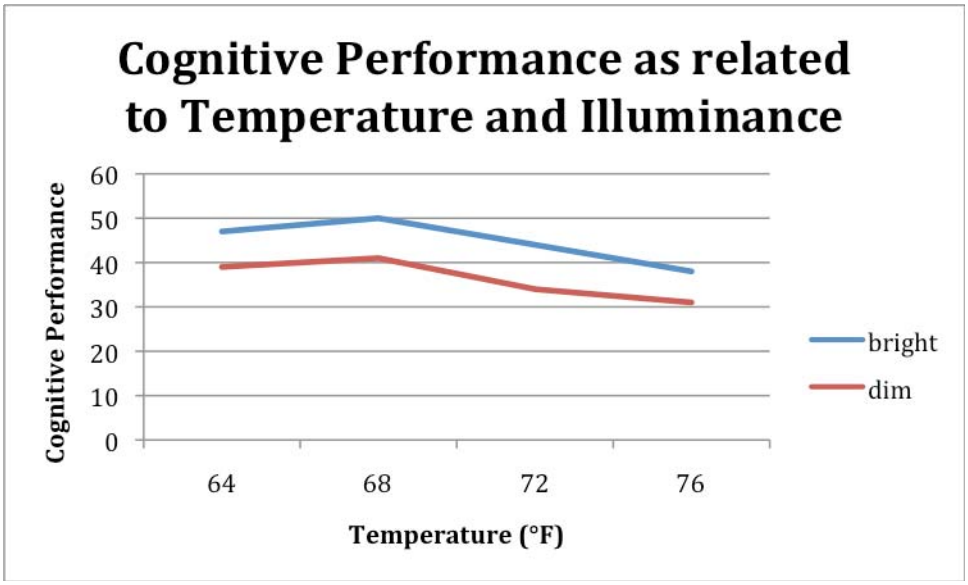

Fig. 4 2-way interaction between bulb type and illuminance with two main effects.

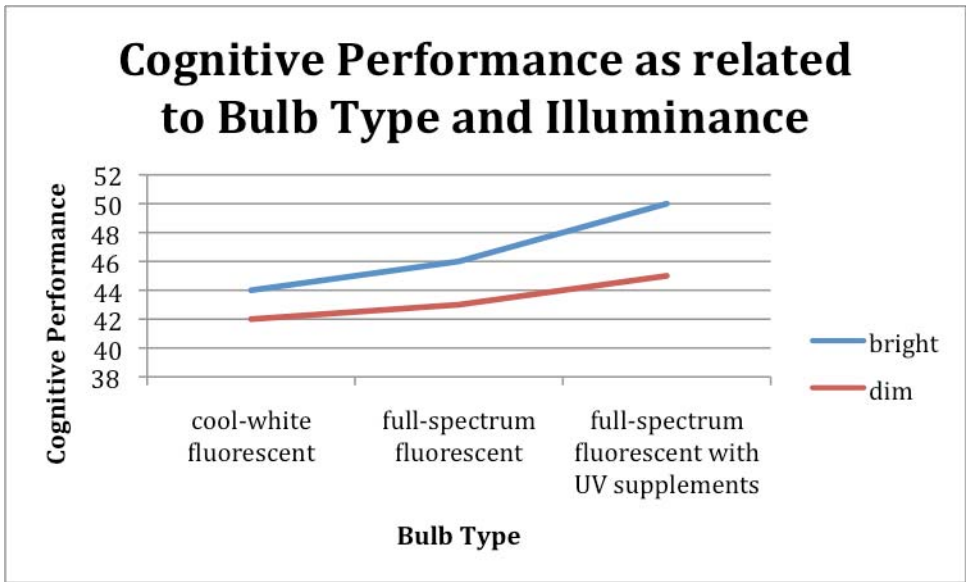

Fig. 5 Effect of temperature on dependent variable scores.