The Influence of Color on Student Emotion, Heart Rate, and Performance in Learning Environments

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Abstract: In this study, six colors (vivid red, vivid blue, vivid yellow, pale red, pale blue, and pale yellow†) were manipulated in a simulated study environment to determine their effects on university students’ learning performance, emotions, and heart rate. It was hypothesized that learning, physiological and emotional states would be affected by different colors in private study spaces. A total of 24 undergraduate and postgraduate students participated in this study. The dependent variables were reading task performance, emotional responses, and changes in heart rate. The results showed that, although participants assessed the situation as relaxed, calm, and pleasant in the pale color conditions, reading scores were significantly higher in the vivid color conditions. Heart rates were significantly affected by hue; they increased in the red and yellow conditions. In addition, the results suggested that, regardless of the degree of whiteness, the hue had a significant impact on participants’ emotions; blue increased relaxation and calmness feelings of participants compared to the other colors. Implications of these findings and suggestions for further research are discussed. © 2015 Wiley Periodicals, Inc. Col Res Appl, 41, 196–205, 2016; Published Online 26 February 2015 in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/col.21949

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INTRODUCTION

Approaches to learning in educational environments are changing. These important changes in learning methods are in response to learners becoming more diverse in age, ability, and background.1 Some people prefer formal learning that is systematic and guided by instruction, such as listening to lectures, while others prefer informal learning without teachers, arising from interactions between individuals via networked mobile devices and group discussion.2 In addition, each person has a different learning style. A particular style is the expression of how people perceive and process information, and is the most comfortable way to learn.3 Melton4 reveals that learners use three basic learning styles: (1) visual learning, which involves viewing, watching, observing and reading; (2) auditory learning, which involves concentrating on lessons or listening to audiotapes; and (3) tactile-kinesthetic learning, which involves touching. Learners remember better when they write, doodle or draw, and participate in laboratory experiments.4

University students often prefer to study in private rooms, especially when they work on complex tasks that need a high level of concentration. Color, in addition to

†The color system used for this study was the Natural Colour System (NCS). Under METHODS, the NCS notations are given for the six colors tested. The colors are in two nuance groups, identified here as “vivid” and “pale.” Vivid colors are to be understood as colors with high chromaticness and little whiteness or blackness; pale colors as having more whiteness than chromaticness and virtually no blackness.

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interior form, space, light, and texture, is a major design element that can be used to enrich the physical learning environment, and it has a significant effect on students, influencing their emotions, performance and heart rate.\(^5\)\(^6\) Previous studies have investigated color in learning environments in terms of college students’ wall color preference for computer classrooms.\(^5\) Other studies have focused on the impact of color on children’s behavior in classrooms;\(^7\) and on the learning and behavior of students with disabilities.\(^8\)

Previous color studies in the field of interior design have focused on residential, work and commercial environments. Color studies in learning environments are scarce, especially for individual study environments. How wall colors in an individual study room influence adult students’ learning performance and concentration is unknown.

Studies of the relationship between color and learning performance have yielded inconsistent results. Some studies failed to detect the effects of color on human performance;\(^9\)\(^10\); however, Hamed and Newport\(^11\) found that children’s hand strength was affected by room color. Hand strength was higher in a pink room and decreased in a blue room, and decreased further when the children moved to a gray room. These findings support the notion that cool colors are calming whereas warm colors are stimulating.\(^12\)\(^13\) Thus, reds make people more active and people are calmed by blues.

Similarly, Kwallek and Lewis\(^14\) have found that color can influence emotion, mood and performance. In their study, although students perceived a white office to be more appropriate and less distracting than red or green offices, they made fewer errors on a clerical task in a red office.\(^14\) Perhaps red is more arousing, while white and green are more calming. If the task is boring, therefore, a red condition may stimulate individuals and enhance their performance. These findings are supported by Kwallek et al.’s\(^15\) study on the effects of nine different colors on short-term worker productivity. The study found that participants performed worse in the white office interior than in any of the other eight interior colors (red, green, orange, yellow, blue, beige, gray, and purple). Further analysis showed that the performance was worse in light colored offices than in dark colored offices. This suggests that the chromaticness and whiteness of a color play a significant role in determining its effects on worker productivity.

In addition, there is a study by Stone\(^16\) on the effects of study setting (private or open-plan), environmental color (blue, red, or white) and study material (reading or math comprehension) on adult students’ mood, satisfaction, motivation and performance. The results indicated that math performance was not influenced by environmental color, but color had an impact on reading performance, with reading performance significantly decreasing in the red condition. The reason for this was that the participants rated the reading task as more difficult than the math task. Therefore, the reading task might demand more attention than the math task. If the color red is over-stimulating, then attention could be distracted, causing a decrease in performance levels. In psychology, the Yerkes–Dodson Law proposes that there is a curvilinear relationship between arousal and performance. Up to a certain point, increased arousal can actually help individuals perform better. After reaching an optimal level of arousal, any increase in arousal will lead to decreased performance.\(^17\)

Color can also affect an individual’s emotional and physiological state. Clarke and Costall\(^13\) point out that the colors green, blue, and violet are generally considered cool, comfortable, relaxing, peaceful, and calming; hence, these colors can decrease anxiety levels. In contrast, red, yellow and orange are considered warm and arousing; hence, these colors can stimulate human feelings and activate people. Neutral colors have less emotional content and therefore less psychological impact. Some evidence shows that there is a correlation between emotion and performance. According to Kuschel, Forster, and Dengler,\(^18\) feelings of happiness tend to facilitate the generation of free associations, which then enhances the ability to solve problems requiring insight.

Color also has an influence on human physiology, such as heart rate, blood pressure, body temperature and vision.\(^19\) Abbas, Kumar and Mcalhan\(^20\) have also studied the impact of color and light on physiological states. The results of this study showed significant changes in heart rate after 2-min exposures to different colored lights with various intensities. They also found an increase in heart rate during exposure to red, indicating that red is arousing. In the blue conditions, the participants’ heart rate decreased slightly, so blue can be considered calming.

On the other hand, there are some studies that did not find any differences in heart rate during exposure to different color conditions. For example, Caldwell and Jones\(^21\) projected red, white and blue lights, equalized for brightness, on a wall covered with white paper. They found no color effects on measures of eye blinks, skin conductance, finger pulse volume, and heart rate. These contradictory results may have been due to the reduced exposure time to the colors, which was less than one minute, and suggest that the time exposure should be long enough to allow participants to adapt to the color conditions before the physiological and emotional states and changes are measured.

The aim of the current study was to examine the impact of colors on adult students’ learning performance and potential mediators of learning performance, namely, emotions and heart rate. For this study, it was hypothesized that learning performance would be affected by different colors such as red, blue and yellow in the learning space. It was further hypothesized that the physiological and psychological processes of learners (namely, heart rate and emotional reactions to the color) would vary as a function of the color of the learning environment. In previous color studies regarding learning spaces, yellow and blue were proposed to be suitable colors for educational environments, and therefore provided a basis for the
present experiment. Other studies have argued that warm colors, such as red, are appropriate for highly active learning areas because they can stimulate communication among students and increase interaction. However, previous studies did not identify which of the numerous yellows, blues and reds are appropriate. Therefore, this research examines colors that might be appropriate and assesses their impact on learning performance.

**METHOD**

The purpose of this experiment was to examine the impact of six colors varying in hue and whiteness on reading comprehension, emotional assessment, and heart rate. The experiment was focused on individual study areas because little rigorous research in the field of color studies has focused on this type of learning environment.

**Participants**

According to G*Power Version 3.1.2, a power analysis program for a variety of statistical tests, at least 24 participants are required to capture a “moderate” interaction between hue and whiteness. Eleven males (45.8%) and 13 females (54.2%) were recruited from undergraduate and postgraduate students at Curtin University in Western Australia. The participants’ ages ranged between 20 and 38 years. Ten participants were international students (with English as their second language), and 14 participants were native English speakers. None of the participants had defective vision, as verified with the Ishihara Color Blindness Test (ICBT).25 Participants were asked to complete a Learning Channel Preference Questionnaire,26 which revealed that all participants were visual learners.

**Color Samples**

Color samples were taken from the NCS Color Atlas which orders colors according to hue, and nuance. The NCS samples were measured and house paints were formulated to be a close match. The NCS notations for the colors used in this experiment were S 1080-R (vivid red), S 0580-Y (vivid yellow), S 1565-B (vivid blue), S 0540-R (pale red), S 0540-Y (pale yellow), S 0540-B (pale blue), and S 0300-N (neutral white) (Fig. 1).

**Instruments**

*Color Blindness.* The Ishihara Color Blindness Test (ICBT) has been used for checking color vision. The test consists of 14 plates, each with a circular image consisting of colored dots as in a pointillist painting. Numerals within the circles of dots are distinguishable if the individual has normal color vision. Only the first 11 plates were used to detect general color deficiency. Each participant had to correctly identify 10 or more plates to be deemed to have normal vision and therefore eligible to participate. Each plate was held at a right angle to the participant’s line of sight. The experimenter instructed the participant to “please read the numbers” and allowed the subject 3 seconds to respond.25

*Learning Channel Preference Questionnaire.* This questionnaire is designed to identify students’ learning style.26 It is divided into three categories (visual, auditory and haptic or kinesthetic) learning styles. Each category contains 10 questions, giving a total of 30 questions across the three categories. Participants were asked to rate each statement on a three-point scale according to how it generally relates to them (three often applies, two sometimes applies, and one never or almost never applies). Scores are totalled in each category; the category with the highest score represents the participant’s preferred learning style.

*Color Emotion Scales.* To assess the emotional response of participants to the colors of the room, nine bipolar color-emotion scales were used in the experiment: dark/light, pleasant/unpleasant, fresh/stale, heavy/light, calm/exciting, dull/sharp, tense/relaxed, warm/cool, interesting/boring.28 Each adjective pair is scored on a seven-point semantic differential rating scale. Participants were asked during the experimental session “What emotional response do you associate with this color?”.
finishing each experimental session, the participants were interviewed and asked “Does this color motivate you to study and help you to focus? Why?” to obtain more in-depth qualitative data.

Physiological Recordings. The Fingertip Pulse Oximeter MD300C21/Beijing Choice Electronic Technology was used to record heart rate. This device consists of a transmitter that is held to the subject’s thumb with a portable digital output mechanism. The equipment is unobtrusive. Two measurements were taken before and during the experiment and the average of each pair was reported.

Performance Assessment. Because all participants were visual learners, reading rather than audio comprehension tests were used to assess learning performance. The participants were asked to read a passage and then they answered seven multiple choice questions. These tests were adopted from the SAT Comprehension Test website. The reading tests were of comparable difficulty across the six color conditions. The passages covered different topics such as science (420 words), social life (473 words), novel (500 words), psychology (488 words), literature (525) and politics (520 words).

Room Design. Two experimental rooms were set up in the School of Built Environment within Curtin University. The first was a neutral waiting room with light gray walls and ceiling and dark gray floor. It was furnished with two chairs and a table (Fig. 2). This served as an adaptation room. The second room was the test room (3.68 m length × 2.88 m wide × 3 m high); it had no windows so that no natural light entered the office, thereby eliminating any fluctuations of natural daylight. The walls and ceiling were painted white and the floor dark gray. Neutral colors would reduce any effects of the room on the colors to be used in the experiment. The experimental room was divided by a partition in order to establish an individual study area (1.80 m long × 1.30 m wide × 3 m high) (Fig. 3). Colors were manipulated by hanging Corflute panels, 180 cm × 180 cm × 2 mm thick, which were painted vivid red (S 1080-R), vivid yellow (S 0580-Y), vivid blue (S 1565-B), pale red (S 0540-R), pale yellow (S 0540-Y), or pale blue (S 0540-B) (Fig. 4). Each colored panel was hung on the wall so that it extended 1.70 m above the top of the desk. The room was furnished with a white student desk and one gray chair. The student desk was centred along the wall, and faced the colored panel. In addition, the desk of the experimenter was located behind the participant on the left side so that she could check the time and measure the heart rate (HR) of the participant during the experimental session. Ambient temperatures of Rooms 1 and 2 were recorded on several occasions on different days; the temperature of both rooms was a constant 25 °C. The rooms were located internally in the basement of a multi-level building; their temperature and humidity vary little throughout the year. The test room was illuminated with four Osram fluorescent tubes (36 W), having a correlated color temperature (CCT) of 3500 °C and a color rendering index (CRI) of 75–82; and 3350 lumens. The average of illuminance was 360 Lux, illuminance and luminance were measured using digital light meter, model Lutron LM-81LX.

Experimental Procedure

The participants in this study were first taken to a waiting room (Fig. 2), which was located outside the door of the test room. In this room, the participants were administered the Ishihara Color Blindness Test (ICBT). After the participants passed this test, they were asked to read the information sheet outlining the experimental procedure. The purpose of the study was explained to the participants, and they were then administered the Learning Channel Preference questionnaire in order to identify their learning styles. This procedure was followed on the first visit only.

The participants were told that they needed to be in the first room for at least five minutes before entering the test room in order to adapt to room conditions and to have their HR measured before the experiment. Participants
were then tested individually in the test room and seated at the desk facing the selected colored panel. The participants were asked first to focus on the colored panel for 5 min. At the end of the five minutes, they rated their emotions on the Color Emotion questionnaire. Waiting for 5 min before completing the color emotion questionnaire reduces any interference from the initial adaptive response to the colored panel. Küller and Mikellids\textsuperscript{30} emphasize the importance of controlling the exposure time to the color stimulus. If the exposure time is too short, such as 1 min, it will measure just the initial response to the color. After completing the color emotion questionnaire, participants’ heart rates were taken again. To assess their learning performance, they were given a reading task, which involved studying the text and then answering comprehension questions for 10 min. Finally, they were interviewed for five minutes to obtain more in-depth qualitative data. All participants were tested individually. To eliminate expectancy bias, participants were not forewarned concerning the exact colors to which they would be exposed. The researcher told them “this experiment looks at how the colors of space impact on the learning activity.”

This process was conducted six times and each time the participant was exposed to a different color condition. The order in which the colors were presented was counterbalanced across participants according to a Balanced Latin Square design.\textsuperscript{31} There was 1 day free between one session and the next which served as a wash-out period, to reduce carry-over effects from one color to the other. The experiment took twenty minutes for each color. Data on the participant’s emotional state, physiological state and comprehension test performance were subsequently analyzed with inferential statistics.

RESULTS

A series of generalized linear mixed models (GLMMs) were tested in order to determine whether the participant’s emotional state, physiological state and comprehension test performance varied as a function of color. The GLMM represents a special class of regression model. The GLMM is “generalized” in the sense that it can accommodate outcome variables with markedly non-normal distributions; the GLMM is “mixed” in the sense that it includes both random and fixed effects. For the present GLMMs, there was one nominal random effect (participant) and two categorical fixed effects (hue: red, yellow, blue; whiteness: vivid, pale). The GLMMs were implemented through SPSS’s (Version 20) GENLIN-MIXED procedure. To optimize the likelihood of convergence, a separate GLMM analysis was run for each outcome measure.

Reading Comprehension

For reading comprehension, the results show that the main effect of whiteness was significant ($F[1,138] = 5.41, P = 0.022$). Reading comprehension scores were significantly higher in the vivid color conditions compared to the pale color conditions. However, the main effect of hue was non-significant ($F[2,138] = 0.39, P = 0.676$).
These results indicate that reading performance did not differ significantly across the three hues. As well as, there was no significant Hue x Whiteness interaction ($F[2,138] = 0.24$, $P = 0.784$) (see Fig. 5).

**Heart Rate Response**

The main effect for hue was significant ($F[1,138] = 11.93$, $P < 0.001$). The graph suggests that, regardless of whiteness, the red and yellow conditions caused increases in heart rate whereas the blue condition caused a decrease in heart rate. LSD (least significant difference) contrasts conducted on the main effect for hue indicated that heart rate increased to the same degree in the red and yellow conditions ($P = 0.315$), and there was a significant difference between the heart rate decrease in the blue condition and the heart rate increases in the red and yellow conditions ($P < 0.001$ for both contrasts). The Hue $\times$ Whiteness interaction, however, was non-significant ($F[2,138] = 0.60$, $P = 0.548$). Likewise, the main effect for whiteness was not significant ($F[2,138] = 3.64$, $P = 0.058$) indicating that changes in heart rate did not differ significantly between the pale and vivid conditions (see Fig. 6).

**Emotional Responses**

For the dark/light scale, the Hue $\times$ Whiteness interaction was significant ($F[2,138] = 5.37$, $P = 0.006$) indicating that main effects of hue and whiteness can no longer be interpreted independently of each other. This interaction is graphed in (Fig. 7). The graph suggests that individuals tended to rate towards the light end of the scale in the pale condition and towards the dark end of the scale in the vivid condition. LSD contrasts conducted across the interaction indicated that red was rated significantly darker than yellow ($P < 0.001$) and blue ($P < 0.001$), and blue was rated significantly darker than yellow ($P = 0.009$) but only in the vivid condition. In the pale condition, there were no significant differences in ratings across hues.

However, the Hue $\times$ Whiteness interaction was non-significant for pleasant/unpleasant ($F[2,138] = 1.27$, $P = 0.285$), fresh/stale ($F[2,138] = 1.40$, $P = 0.250$), heavy/light ($F[2,138] = 0.86$, $P = 0.425$), calm/exciting ($F[2,138] = 0.21$, $P = 0.811$), tense/relaxed ($F[2,138] = 0.38$, $P = 0.687$), warm/cool ($F[2,138] = 0.67$, $P = 0.515$), dull/sharp ($F[2,138] = 1.05$, $P = 0.353$) and interesting/boring ($F[2,138] = 0.41$, $P = 0.668$). For these scales, therefore, each of the two main effects can be interpreted independently of one another.

The main effect of whiteness was found to be significant in terms of “pleasant/unpleasant” ($F[1,138] = 14.21$, $P < 0.001$), “fresh/stale” ($F[1,138] = 11.88$, $P = 0.001$), “heavy/light” ($F[1,138] = 71.10$, $P < 0.001$), “calm/exciting” ($F[1,138] = 7.52$, $P = 0.007$), “tense/relaxed” ($F[1,138] = 31.91$, $P < 0.001$), “warm/cool” ($F[1,138] = 20.05$, $P < 0.001$) and “dull/sharp” ($F[1,138] = 8.98$, $P = 0.003$). These effects indicate that, regardless of hue, the pale conditions were rated as significantly more pleasant, fresh, calm, dull, relaxed and cool than the vivid
conditions. In addition, pale colors tended to be rated as light whereas vivid colors tended to be rated as heavy. However, whiteness was found to have no significant effect on “interesting/boring” ($F_{[1,138]} = 0.45$, $P = 0.502$) indicating that, regardless of hue, ratings did not differ significantly between the pale and the vivid conditions.

The main effect of hue was significant for “pleasant/unpleasant” ($F_{[2,138]} = 11.32$, $P < 0.001$), “fresh/stale” ($F_{[2,138]} = 10.33$, $P < 0.001$), “heavy/light” ($F_{[2,138]} = 12.53$, $P < 0.001$), “calm/exciting” ($F_{[2,138]} = 12.56$, $P < 0.001$), “tense/relaxed” ($F_{[2,138]} = 20.27$, $P < 0.001$), “warm/cool” ($F_{[2,138]} = 30.69$, $P < 0.001$) and “interesting/boring” ($F_{[2,138]} = 3.59$, $P = 0.030$). LSD contrasts conducted on the main effect for hue indicated that, regardless of whiteness, blue was rated significantly more pleasant than either red ($P < 0.001$) or yellow ($P = 0.003$); no significant difference was found between red and yellow ($P = 0.414$). Blue was rated as significantly calmer than either red ($P = 0.007$) or yellow ($P < 0.001$); and red was rated significantly calmer than yellow ($P = 0.025$). Blue was rated significantly less tense than either red ($P < 0.001$) or yellow ($P < 0.001$); there was no significant difference between red and yellow ($P = 0.231$).

In addition, blue was rated significantly cooler than either red ($P < 0.001$) or yellow ($P < 0.001$); there was no significant difference between red and yellow ($P = 0.696$). Moreover, the participants rated blue as significantly more interesting than red ($P = 0.008$); there was no significant difference between red and yellow ($P = 0.152$) or between blue and yellow ($P < 0.219$). Red was rated as significantly less fresh than either blue ($P < 0.001$) or yellow ($P = 0.001$); there was no significant difference between blue and yellow ($P = 0.277$). Red was also rated as significantly heavier than either blue ($P < 0.001$) or yellow ($P < 0.001$); there was no significant difference between blue and yellow ($P = 0.346$).

A nonsignificant effect of hue was found for “sharp/dull” ($F_{[2,138]} = 3.06$, $P = 0.050$) indicating that ratings did not differ significantly across the three hues.

Interview Results

Each participant attended a post-test interview. For each of the six colors, participants were asked “does this color motivate you to study and help you to focus? Why?” Responses to this question would provide subjective data regarding the color’s impact on emotions and learning performance, and general reactions to the color. Participants were briefed before the interview so that they fully understood its purpose and the topics that would be covered. The responses for each color condition were analyzed for commonalities and differences. Responses were coded and subjected to a thematic analysis. Qualitative findings were categorized into seven themes: emotion, physical bodily, association, spatial properties, motivation, intellectual activity and task.

Pale Colors

The results indicated that hues with a higher level of whiteness such as pale blue and pale yellow evoked the more active emotions, and had a more positive impact on the physical body, motivation, intellectual activity and spatial properties. For example, 70% of participants believed that pale blue was associated with calmness, happiness, relaxation, comfort, and peacefulness, because it is related to the calming aspects of nature such as the sky and water. In addition, participants thought that pale blue made them active, motivated them for study and increased their concentration levels. The participants made the following comments regarding pale blue:

“I feel excited with this color because it is associated with nature like sky and water . . . I feel I am in an open space may be it is a cool and peaceful color. It did increase my concentration on the reading task . . . so it motivates me to study” (Participant 8)

In addition, 58% of respondents also believed that pale yellow had positive effects on learning performance. It was associated with positive feelings such as happiness, cheerfulness, and relaxation. The participants described it as a sun, a source of light, and said that it made them feel active, awake, and enlarged the space; it focused their attention on the reading task and motivated them to study:

“I feel good . . . it is very motivated color for study because this color brings light . . . and I like shiny colors. It helps me to be active and alert . . . more focused on reading task” (Participant 21)

However, 66% of the responses indicated that pale red was considered boring, annoying, bright, warm and uncomfortable, because it was believed to increase nervousness, tiredness and distraction. In addition, the participants saw pale red as a very feminine color, suitable for bedrooms but not for learning environments. As a result, it was agreed that pale red did not motivate them to study or focus on the reading task:

“It is tense color . . . I cannot focus with it because it is slightly bright . . . and it is girly color” (Participant 11)

“This color makes me feel nervous and stress because it is slightly bright and there is a strong reflection that causes distraction when I read. I cannot focus and it does not motivate me to study . . . it may appropriate for party activity” (Participant 2)

Vivid Colors

The majority of participants agreed that the vivid red and the vivid yellow were not suitable colors for individual study areas because they had a negative impact on their emotional state, physical body, intellectual activity and motivation. For example, 66% of participants reported that vivid red was associated with depression, annoyance, discomfort, warmness, and with negative concepts such as blood, war, and danger. Furthermore, the participants felt nervous and stressed, and said that the color distracted their vision because of its highly reflective nature. The participants agreed that vivid red did not
motivate them to study for any length of time, and they found it difficult to focus on the reading task. The participants made similar comments about vivid red:

“I feel uncomfortable with this color because it is dark color ... doesn’t help me to focus because it is distractive color and causes eye fatigue ... It is very active but it doesn’t encourage me to study” (Participant 4)

“It doesn’t help me to study because it is related to war, blood, and danger ... it’s too vivid so I cannot focus on the reading task” (Participant 17)

Likewise, vivid yellow was considered an uncomfortable color for studying. It was perceived as a very bright, annoying and strong color. Moreover, 75% of the participants reported that vivid yellow increased their discomfort level. This occurred, they believed, because yellow with its high chromaticness had a negative effect on the physical body. Participants also thought that the reflective nature of vivid yellow was distracting, caused eye fatigue, and made them feel nervous, tired and hot. In addition, it was reported that vivid yellow was very arousing and they believed that it may be suitable for tasks that demand a high level of activity such as sport. Furthermore, the participants confirmed that it was difficult to concentrate on the reading task; and therefore, not ideal for motivating them to study:

“It is so bright color ... I feel hotness with this color it is like a sun ... It is unmotivated color for study may it good for sport activity or for kids’ places” (Participant 6)

“It is distractive and annoying color ... uncomfortable for eyes because it reflects too much light. It does not motivate me to study” (Participant 22)

A few participants 25%, however, associated vivid yellow with positive feelings:

“It is shiny color it helps me to read clearly and concentrate on the reading task ... It is active more energetic and natural color like daylight” (Participant 3)

In contrast, vivid blue was considered an appropriate color for learning environments. For example, 62% of participants thought that it had positive effects on their emotions, performance, physical body, and concentration levels. It was perceived as a calming, cool, quite bright and comfortable color, and related to aspects of nature such as the sky, beach and summer. The participants reported that vivid blue made them awake and active, and helped them to concentrate. They commented:

“It is comfortable and it makes me awake and active because it is related to clear sky and sea water and I really like this atmosphere to study ... more concentrated” (Participant 3)

Table I summarizes the results of the interviews.

### DISCUSSION

The main goal of the present research was to investigate the effects of different colors on students’ learning, emotions and heart rates within the individual study areas of university libraries. The study took place in a full scale space that was designed to simulate a typical space for individual study in the university library.

#### Heart Rate Responses

Baseline heart rate was recorded in the waiting room (gray color condition), and then recorded again during the experimental session after 5-min exposure to each of the six colored panels. The results indicated that changes in heart rate did not differ significantly between pale colors and vivid colors. However, hue induced significant changes in heart rate. Red and yellow increased heart rate whereas blue decreased heart rate. Heart rate increased to the same degree in the red and yellow conditions \( P < 0.001 \); there was a significant difference between the heart rate decrease in the blue condition; and the heart rate increased in the red condition \( P < 0.001 \) and the yellow condition \( P < 0.001 \). This finding supports the notion that color has a strong impact on the physiology of people who stayed in the colored room. In addition, several color studies have indicated that long-wavelength colours such as red and yellow are more arousing than short-wavelength colors such as blue and green.

It seems that warm colors such as red and yellow, regardless of whiteness or chromaticness, have arousing properties that stimulate people and make them feel more active, producing increases in heart rate. These results support the hypothesis that heart rate will vary as a function of the color of the learning environment.

#### Reading Comprehension

Reading comprehension varied across the different colors as expected. Specifically, the whiteness dimension (but not the hue) had a significant effect on reading comprehension. Reading comprehension scores were higher for the vivid colors compared to the pale colors. These findings agree with the findings of Kwallek et al., which showed that participants made more errors in the paler color offices than in the darker color offices. This effect seemed to be related to the whiteness of the hues. Pale colors may, in some sense, be more distracting than vivid colors.
colors. This suggests that the chromaticness and whiteness (NCS nuance) of a color play an important role in determining the effects of the color on students’ learning performance.

The findings are also consistent with the notion that vivid colors are more arousing than pale colors. If the reading tasks are difficult, therefore, the vivid color conditions may increase arousal to optimum levels, thereby enhancing learning performance. This finding supports the Yerkes–Dodson Law about the relationship between arousal and performance.17 Another explanation for this finding is that the vivid colors were considered to be more distracting than the pale colors because of their higher chromaticness; perhaps participants become more focused on the reading tasks in an attempt to ignore the distracting stimulus. Interestingly, participants who felt positive in the pale color conditions showed enhanced learning in the vivid color conditions.

**Emotions**

Consistent with the findings of Küller, Mikellides, and Janssens,6 and Ou et al.,33 the results clearly indicate that both hue and whiteness had a strong impact on participants’ emotional reactions. The results also supported the second hypothesis that emotions will vary as a function of the color of the interior environment. The participants felt more positive in the pale color conditions compared to the vivid color conditions, because pale colors were perceived to be pleasant, fresh, calm, relaxed, light, cool and less sharp. These findings are consistent with those of Manav,34 which showed that colors with high value (whiteness) were associated with positive emotional responses. The participants reported that pale colors increased the feelings of relaxation and calmness, making them less active and energetic and therefore less motivated to study.

Emotion ratings also differed significantly across the three hues. It was found that blue put the participants into a more positive state, because it was perceived to be more pleasant, fresher, calming, relaxing, cooler, lighter, more interesting and less sharp compared to the other two hues. These findings are contrary to previous findings which showed that hues did not have a significant impact on emotion.9

**Interviews**

The participants were interviewed individually and asked about the impact of each color on their emotions and learning performance. They reported that, in addition to the effect of color on emotions, color can have a perceived impact on the physical body, motivation, intellectual activity, and spatial properties of the environment. In general the blue colours, whether pale or vivid, were considered appropriate colors for learning in the individual study area. The blues were perceived to be relaxed and calm because of their association with the calming aspects of nature such as the sea and sky. The blues were also comfortable for vision, and enlarged subjective space by virtue of their coolness and lightness. Compared to pale blue, vivid blue helped participants remain alert, active and focused for a longer time. This finding is consistent with the results of the comprehension test, which indicated that scores were higher in the vivid color conditions compared to the pale conditions. If the reading task requires careful attention, then colors such as vivid blue can help students to be more focused on their tasks. In contrast, pale blue can be helpful for tasks that require insight such as creative or mathematical tasks. Perhaps subjects in the vivid blue condition attempted to ignore the bright surrounding color by concentrating more on the test, thereby making fewer errors.

Pare yellow was also perceived as more suitable for studying in the individual study room than vivid yellow. The participants reported that pale yellow had a positive impact on their learning performance and it was a color that motivated them for studying. They concurred that it is related to positive emotions such as happiness, cheerfulness and relaxation. The results corroborate previous research concerning the qualities of yellow. For example, Clarke and Costall13 and Ballast12 found that yellow was associated with smiling, cheerfulness and joviality. The participants reported also that pale yellow was like the sun, it reflects light and makes them feel active and awake, which helped them focus on the reading tasks and motivated them to study. However, these subjective reports are inconsistent with the objective data which showed that performance on the comprehension task was poorer in the pale color conditions compared to the vivid color conditions.

With the red conditions, the results suggest that vivid red and pale red are unsuitable for learning, having a negative impact on intellectual activity. Specifically, participants reported that these colors impaired their concentration. They claimed that vivid and pale red increased stress levels because they strongly reflected light, were distracting and over stimulating. This finding is inconsistent with the comprehension test results for the vivid conditions. In general, most participants believed that pale colors with high whiteness would be appropriate color schemes in learning environments because they are considered calm and relaxing. However, the calmness and relaxation aspects may not help students to be alert and active. Therefore, the participants performed better in the vivid color conditions, because these colors have arousing properties that stimulate neural activity. According to Draper and Brooks,35 colors should arouse and activate the brain in order to help students undertake activities in the learning environment within the library.

**CONCLUSION**

The study found that color affected emotions, heart rate and the reading performance. Hue and whiteness had a significant impact on students’ emotions. The pale colors were rated more positively than the vivid colors because they were considered to be calming and relaxing. Blue
and yellow put the participants into a more positive state. In addition, the results suggest that whiteness had a significant impact on learning as reflected in comprehension test scores; comprehension was significantly better in the vivid color conditions. Furthermore, heart rate was significantly affected by hue; it increased in the red and yellow conditions and decreased in the blue condition. This suggests that colors can evoke physiological and emotional responses in individuals that focus attention and thereby facilitate learning.

This study has some limitations. First, although the number of participants was calculated by a power analysis program, the size of the sample is considered small. Also, the time spent studying in various colour conditions was short. In addition, this study was focused on the impact of colour on adult students, therefore, it may not be applicable for children or elderly.

Thus, more research is needed to investigate these points. The next step would be to conduct long-term studies in real environments. In addition, research is needed to address the effect of colour in other learning spaces such as group study rooms and computer study areas. The proposal that physiological and emotional reactions mediate the impact of color on learning remains to be tested.