Color and Visual Comfort

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Based on a presentation by Nancy Kwallek, Ph.D., IIDA, IDEC

Figure 1: English physicist Sir Isaac Newton discovered that prisms can separate white light into its component colors.

Introduction

Ever since Sir Isaac Newton proved the existence of all visible colors of the spectrum in an intercepted beam of sunlight with a triangular prism, people have been fascinated with the qualities of color. Writings on the effects and complex nature of color in art, culture, psychology, and religion are extensive. Not surprisingly, different theories and preconceptions have been formed about visual comfort in interiors, mainly on the use of color and its effects on people. By now most people are familiar with the common beliefs about the relationship between color and mood or feelings, such as red induces energetic feelings, blue has a calming effect, and yellow makes people feel uplifted. However, little experimental research has been conducted and most of the findings are questionable or outdated. Although color is an integral part of design, little empirical evidence exists to support some of the popularly held ideas about the effects of color on task performance and human psychological well-being. For these reasons, a series of experiments have been conducted over two decades on the effects of interior color on workers’ productivity in an office environment, focusing on the changes in office workers’ mood, task performance, and job satisfaction with different interior colors.

What is visual comfort?

In order to develop a better understanding about the influence of color on visual comfort, we need to first understand the meaning of this term and the variables that interact with it. Visual comfort exists when the perceptual faculties in the human brain can operate without interference. When there is no inhibition of perception, the basic functions of the eyes, such as vision, speed, and contrast sensitivity, are optimized. This optimization of the basic perceptual functions is very important while perusing optimal working conditions. Some factors that can inhibit perception in an interior setting include incorrect distribution of light density, glare, poor color selection, and inappropriate interior design. While this paper focuses on color selection, other aspects of an interior should also be taken into consideration when designing for visual comfort.

The influence of color

We experience color as a fundamental quality in our visual perception. Based on an overall impression, the eyes receive information regarding the aesthetics, material characteristics, and utility of a particular object. Since color selection itself has a great impact on the way we perceive our interior environment, it
contributes to the psychological and physical well-being of the occupants in a particular room. Therefore, designers have the responsibility to create harmony between the possible color and the intended function of an object in a particular space.

Three functions of color

Color can fulfill the following functions:

• Indicative function: Color clarifies the invitational character, utility, and function of an object by indicating visual validity, condition, material, purpose, or functional structure to observers. Color thus suggests the real qualities and functions of an object. One example is the use of red and blue on faucet handles to indicate the source of hot and cold water.

• Symbolic function: Color communicates imaginary object qualities. While color projects values, it can also take on random symbolic meaning. One example of this function is the use of red for sports cars to convey a sense of speed and power.

• Aesthetic function: Color can serve as a decorative element or as a part of a formal composition. It is evaluated according to its affectivity and expression. The decisive aspect here is the formal aesthetic relationship between different colors as judged by contrast, harmony, field size, and color distribution.

These three functions of color moderate the relationship between the colors’ effect and the sense of visual comfort. The value of interior color is not only determined by the function of the room but also by the needs and preferences of its users.

Color and its psychological impact

One common belief associated with color is that color has a direct emotional impact on individuals. Warm colors, such as red, orange, and yellow, are associated with active emotional states, while cool colors, such as blue, green, and purple, are associated with restful emotional states. Warm colors are supposed to be stimulating and make people feel excited and happy. In contrast, cool colors are believed to be calming and make people feel secure and relaxed. In addition, there is also a common belief that the color of a room is associated with a certain temperature, which scholars term the “hue-warmth hypothesis.” According to this hypothesis, a red room would require less heating than a blue room because the red room is perceived to be warmer than the blue room. However, studies show that while the perception of warm and cool colors influences people’s subjective assessment of an interior space, it seems to have no impact on occupants’ actual thermal comfort. Therefore, the interior color has more psychological than physiological effects on occupants in terms of thermal comfort.

Myths and preconceptions

These common beliefs about interior color have allowed individuals to make assumptions about its impact on interior space occupants. While there is limited empirical evidence suggesting the physiological impacts of color, the prevailing view is that warm colors are more arousing than cool colors, and that red (to a lesser extent orange and yellow) can speed up psychomotor reactions and, if excessive, can impair efficiency of work performance. The experimental findings that support this view are sparse, often contradictory, and have limited usefulness in predicting the effects of color in the interior environment on office workers’ productivity and psychological well-being.

One of the studies conducted on how color can have a positive effect on people’s behavior is the pink prison experiment in the late 1970s. In this study, inmates in Seattle, Washington were placed in a bright pink prison holding cell and they were later found to exhibit less aggressive traits. Their findings became so well accepted that many prisons around Canada and the U.S. started to adopt this exercise. However, when the experiment was replicated later, the same tranquilizing effects were not detected. The researchers concluded that the tranquilizing effect was due to the novelty of the color change in the prison cells and not due to the pink color per se.

Still, the notion about the soothing effect of pink in prison cells persists. In the 1990s, a university’s sports team painted the visiting team’s locker room pink, believing that the color would make the players of the opposing team less aggressive. In 2003, the U.K. followed suit and painted some prisons pink. In a more recent case, a sheriff who is in charge of a 100-year-old jail in Texas dyed or painted everything pink - cells, uniforms, underclothes, shoes, and towels – in order to decrease aggression among prisoners and discourage their return to jail.

The effect of color in these real-life examples is questionable, and many of the notions about color making people feel calm or depressed are debatable. For these reasons, a series of experiments were designed and conducted to determine the effects of color on the productivity and well being of office occupants.

Experimental studies

The following series of experimental studies aims to understand more fully how color within the work environment affects its occupants. These experiments have been conducted over the past 20 years in a controlled environment of closed office spaces to determine the possible effects of color on workers’ well being, satisfaction, productivity, and performance.

Study #1: Color of interiors and productivity and mood

This experiment focused on the effect of color on task performances. It was designed to analyze the effects of a red office environment ver-
sus a blue office environment on participants’ typing task and mood. The general assumption is that warm colors have more arousing effect on human behavior than cool colors. In this study, we postulated that there would be greater anxiety and arousal among the occupants in the red office than the occupants in the blue office. Typing performance was also measured to see if the overall performance of occupants was affected by office color.

Subjects

Thirty-six subjects participated in this experiment. There were equal numbers of female and male subjects. One third were between the ages of 18 and 25 years, another third were between the ages of 26 and 35 years, and the last third were 36 years or older. The subjects’ typing performance was estimated and categorized into low (15 to 30 words per minute), medium (30 to 45 words per minute), or high (45 to 60 words per minute) performance.

Materials

Office interiors: Each office was 8ft. wide, 11ft. 9in. long, and 8ft. 9in. high. All four walls (including the back of the door) in each of the spaces were painted red (Munsell color notation: 6.05R 4.59/11.15) or blue (Munsell color notation: 1.51PB 4.95/8.05). The temperature for both offices was maintained between 76°F and 81°F. Each office was furnished with two desks, three chairs, books, a window, a lamp, a small plant, typing paper, and an electric typewriter.

Tests: Each subject was given information to type onto three University of Texas business forms (gift processing form, purchase voucher, and request for appointment form). If the subjects finished these forms in the allotted time, they were provided with a copy of an essay to type. After 20 minutes of typing, each subject filled out the Employee Screening Questionnaire (ESQ), which provides a profile over eight categories: anxiety, stress, depression, regression, fatigue, guilt, extroversion, and arousal.

Procedure

There were four orders of procedure (nine subjects in each order). In each order, the subjects were pre-tested on their typing ability and they were matched according to the result of their typing test. Subjects in each order were instructed to do one of the following things: stay in the red room for the entire experiment; stay in the blue room for the entire experiment; start in the red room in the first half of the experiment and shift to the blue room in the second half; and start in the blue room in the first half of the experiment and shift to the red room in the second half.

The experimental procedure started by escorting the subjects to one of the monochromatic rooms and they were given the University’s forms to fill out for 20 minutes with an additional five minutes warm-up time. Next, the subjects were given the ESQ. After a five-minute break outside of the office, subjects were either back in the same room or moved to the other monochromatic room and repeated the same tasks: filling in forms for 20 minutes and then responding to the same ESQ. All subjects were asked to type on the same forms. Carbons were attached to the typewriter to keep track of the errors they made while typing. The dependent variables included the number of words typed, number of errors made, and the responses on the ESQ.

Results

Analysis of variance was performed with repeated measures using the Statistical Analysis System (SAS) software. The only significant main effect in the analyses was the total number of errors made on the typing task.

- In terms of typing performance, the subjects who switched to a different office half-time during the experiment made a greater number of errors than those who stayed in the same office for the entire experiment. The group that switched from the blue office to the red office made a significantly greater number of errors than the other three groups. Specifically, women who went from the blue office to the red office made more errors than women in any other group.

- In terms of mood, the responses from the ESQ showed that the red office was associated with anxiety, whereas the blue office was associated with depression among subjects. Also, changing color environment (offices) was associated with increased arousal among subjects. In addition, the fatigue measure on the ESQ was lower for women who switched from the blue office to the red office. This would indicate that the increase in errors in the second half of the experiment was not due to the fatigue effect.

Study #2: Occupants’ performance, mood, and preference in a red, white, or green office

This experiment assessed the effects of a red versus green versus white office environment on occupants’ productivity, mood, and preference. Based on the findings in the first study, it was predicted that the subjects in the red (warm color) office would feel more tension and show less preference toward the office color than the subjects in the green (cool color) office; they would also make more errors in their task performance than the subjects in the green office. The subjects’ task performance and mood and preference responses in the white (neutral color) office would fall in between the subjects in the red office and the subjects in the green office.

Subjects

A total of 222 psychology students (111 males and 111 females) from The University of Texas at Austin participated in this experiment. The average age of the subjects was 18.6 years.

Materials

Office interiors: Each office was 8ft. 8in. wide, 11ft. 6in. long and 8ft. high. All four walls (including the back of the door) in each of the spaces were painted bright red (Munsell color notation: 6.05R 4.59/11.15), bright green (Munsell color notation: 3.45G 4.44/7.89) or white (Munsell color notation: 9.75YR 8.74/0.45). The temperature for the three offices was maintained between 72°F and 78°F. Artificial lighting was set up identically in each office, which consisted of four Westinghouse recessed fluorescent bulbs (each with 40W of cool white light F40CW) and a desk lamp with a three-way 120V incandescent bulb set at 80W radiating through a white translucent lampshade. Each office was furnished with a desk, a phone, a table, a filing cabinet, two chairs, a pencil holder, a window with a blind, a lamp, a small plant, and various other decorative amenities. The furnishings were in neutral tones and did not create a contrast with any of the primary hues of the offices.

Tests: Each subject completed the Profile of Mood States (POMS) questionnaire that determined a profile of six factors: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. Each subject was also asked to perform a two-part clerical test (name and number proofreading tasks) aimed to measure perceptual speed and accuracy of task.

Procedure

Three subjects were tested at a time in one of the three offices. Each of the subjects completed the POMS questionnaire in a separate pre-test area, which was painted the same white color as the white testing office. Then, they were escorted into the offices where they completed a personal information sheet, fol-
followed by the name and number proofreading tests. They were given 20 minutes to work on each test. Later, the subjects were instructed to complete the POMS questionnaire one more time and were asked whether they would like to work in their designated office, whether they liked the color of the office, whether they found the color of the office distracting, and whether they thought the color affected their performance and/or mood.

Results

Overall, there was a significant difference in the number of errors the subjects made as well as the post-test POMS and preference responses in the three different offices.

• In terms of performance, the subjects in the white office made more errors than the ones in the red office. In addition, females performed better than males on the proof-reading tasks overall.

• In terms of mood, there was significantly lower confusion-bewilderment post-test mean score for the subjects in the white office compared to the subjects in the green office.

• In terms of preference, the subjects who worked in the white office reported that they liked working in their office more than the subjects in the red office. The subjects in the white office were also more likely to believe that the color had an effect on their work compared to the subjects in the green and red offices. Contrary to the hypothesis, the subjects in the green and in the red offices showed no significant rating difference in terms of whether the office color affected their work.

• The subjects who worked in the white office rated their office as less distracting than the subjects who worked in the red office. Nevertheless, there were more errors made by the subjects in the white office than the subjects in the red office. In addition, more male than female subjects working in the red and white offices found the color of the office distracting, while more female than male subjects working in the green office found the color of their office distracting.

Study #3: Effects of nine monochromatic office interior colors on clerical task and worker mood

The goal of this experiment was to test the effects of the main colors of the Munsell Color Circle (green, blue, purple, red, yellow, and orange) and three neutral colors (white, gray, and beige) on human performance, mood, and color preference in an office environment. Specifically, the effects of high-or-low value colors, high-or-low saturated colors, and warm-or-cool colors on task performance, mood, and preference of both genders were investigated.

Subjects

There were a total of 675 psychology students (334 females and 341 males) of The University of Texas at Austin who participated in this experiment. The mean age of the subjects was 18.89 years.

Materials

Office interiors: Using the same office spaces in Study #1 and Study #2, all four walls in each of the offices were painted over with one of the following monochromatic colors in three phases (each phase consisted of three
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different colors): red, white, green; orange, yellow, blue; and beige, grey, and purple. The temperature, lighting, and furnishing of the three offices were established in the same way as in Study #2.

Tests: There were three different tests that each subject was asked to complete: the Profile of Mood States (POMS) questionnaire, the Minnesota Clerical Test (MCT), and a final questionnaire consisting of questions such as whether the subjects liked to work in their designated office, whether they liked the color of their office, and whether they found the color of the office to be distracting.

Procedure

While the subjects were randomly assigned to one of the nine offices, the administrator assured that there were a similar number of male and female subjects in each office. The subjects’ mood states were tested using the POMS questionnaire before and after task performances. First, the POMS questionnaire was administered in a separated pre-test area so that the subjects’ mood could be examined before being exposed to the office environment. After placement, the subjects completed a personal form, followed by name and number proofreading tests; subjects were given 20 minutes to complete the clerical tasks. Then, they were asked again to complete the POMS questionnaire inside the office. Finally, the subjects completed a questionnaire, asking their opinions about the color of their office. Each subject spent 45 minutes in his or her office overall.

Results

• In terms of task performance, subjects in the light offices (white, beige, yellow, and grey) made more errors than subjects in the dark offices (red, blue, green, and purple).

• In terms of mood, male subjects reported more depression, confusion, and anger in the higher saturated (brighter) offices, while female subjects reported more depression, confusion, and anger in the lower saturated color (duller) offices. In addition, subjects believed that the warm colors were more arousing than the cool colors.

• In terms of preference, subjects showed the least preference working in the orange and purple offices, while most preferred working in the white and beige offices. Subjects also believed the white office to be the least distracting, but they made more errors working in it. Overall, most subjects preferred a white color for the interior color of an office.

Study #4: Impact of three interior color schemes on occupants’ mood, preference, and performance relative to individual environmental sensitivity

The purpose of this study was to examine how color within the work environment affected mood and performance of office workers over a four-day work week. The design limitations of previous color research studies were counteracted by making this study as realistic as possible. Unlike the other experiments, this study used color schemes (explained below) instead of monochromatic colors to resemble the variations of hues, values, and saturations in real world offices. The role of individuals’ environmental sensitivity (i.e., ability to screen and filter external stimuli) was also considered in terms of its role in moderating the relationship between interior environment and occupants’ mood, preference, and performance.

Subjects

A total of 90 office workers (64 females and 23 males) completed the four-day work week experiment. The mean age of the subjects was 33.2 years. Workers were recruited through the state Human Resource Center, placement of ads in the city newspaper, and other job recruitment centers in the city.
Materials
Office interiors: Each office was 8 ft. 8 in wide, 11 ft. 6 in long and 8 ft. high. Office #1 was painted “NASA” white (Munsell Color Notation: 2GY 9/5) on all four walls and the back of the door including the desk return and appointments. Office #2 was painted red (Munsell Color Notation: 5R 5/12) for the top two-thirds of the wall area (including the door) and the lower third wall area, desk base and return were painted blue-green (Munsell Color Notation: 5BG 7/5) and for accent and trim molding, the color selected was pale pink (Munsell Color Notation: SR 9/2). For office #3, the predominant color was light blue-green (Munsell Color Notation: 5BG 9/2) for the upper two-thirds of the room and the back of the door. Medium red (Munsell Color Notation: SR 7/7) was selected for the lower third wall area, desk and return, and for the accent and trim molding, bright blue-green was selected (Munsell Color Notation: 5BG 5/8). The temperature for the three offices was maintained between 73°F and 75°F. The acoustics were buffered with “white noise” machines. Artificial lighting was set up identically and it was measured using an illumination quality meter, Model IQ-2 by Prime Color Inc. In each office, there was an office desk and return, a posture chair, an occasional chair, a memory typewriter, a wall clock, and three framed black-printed generic certificates on the wall opposite to the desk. Desk accessories included a wooden paper tray and a wooden card file box, a metal tape dispenser, a stapler, a pair of bookends, a book, a telephone, a green plant, a phone message pad, and a clear glass cup holder for pens and pencils.

Tests: For this experiment, the following tests and questionnaire were administered: the Jenkins Achievement Striving Activity Scale (JASAS), the Eysenck Personality Inventory (EPI), the Mehrabian Stimulus Screening Questionnaire (SSQ), the Ishihara Color Blindness Test (ICBT), the Profile of Mood States (POMS) questionnaire, the Minnesota Clerical Test (MCT), and a questionnaire on interior colors.

Procedure
All prospective subjects were screened before being assigned to the experiment. They were administered the JASAS, EPI, SSQ, and the ICBT, and a timed typing task. After the screening process, subjects who did not meet specific requirements or had unsatisfactory scores on the tests were eliminated from the experiment. A total of 400 were scheduled for screening, but only 200 showed up for the actual screening and subsequently only 120 passed the criteria. Furthermore, due to no-shows, cancellations and other circumstances, only 90 subjects completed the experiment. The subjects were matched across three office conditions based on nine performance, demographic, and mood-related characteristics, including typing speed, scores on the SSQ, scores on the JASAS, sex, age, handedness, and the three-part inventory scores of the EPI.

The subjects were asked to fill out the POMS questionnaire twice a day, once at the beginning of the day in the reception area, and then at the end of the day in the office. The MCT was administered in the offices in the morning on the first day and in the afternoon of the last day. In between the questionnaires, the subjects were asked to perform a typing task, a text proofreading task, and a zip code proofreading task in the morning and afternoon for all four work days. At the end of the experiment (fourth day), the subjects completed the questionnaire regarding their preference toward the interior colors.

Results
Regression models were used with office color scheme and individual’s stimulus screening ability as the independent variables and with responses on mood states, job satisfaction, preference, and task performance as the dependent variables.

- **Task Performance.** Subjects who were low screeners (those who were more affected by their environment) had worse performance in the predominantly red office and had better performance in the predominantly blue-green office. In contrast, subjects who were high screeners (those who were less affected by their environment) had better performance in the predominantly red office and had worse performance in the predominantly blue-green office. Subjects who were low screeners also had better performance in the white office than in either the red or blue-green office. In addition, subjects who were high screeners had better performance in the red office than in the blue-green office.

- **Mood.** Subjects in the predominantly red office reported more dysphoria than subjects in the predominantly blue-green office. In addition, low screeners reported more depression than high screeners in the red office. They also reported more anger and depression than high screeners in the white office.

- **Preference and Job Satisfaction.** Subjects in the white and predominantly blue-green offices reported higher job satisfaction compared to those in the predominantly red office. Moreover, subjects who were moderate to high screeners expressed greater job satisfaction than subjects who were lower screeners.

Conclusion
Although there are many myths and preconceptions about interior color and visual comfort, it is certain that color impacts our mood and performance. However, the mechanism in which how color affects our visual comfort differs from these common beliefs. This series of experiments, which was performed in a controlled environment, provide reliable evidence for color theory and the effects of color on occupants in an interior environment.

Based on these studies, the findings suggested that color scheme alone may impact occupants’ mood. However, no link was found between worker mood and worker performance. Positive mood characteristics did not lead to higher productivity, contrary to the popular assumption. This suggested that color may have differential impacts on mood and performance respectively.

Another finding was that while white has not been considered to be the most appropriate office color for productivity, the office occupants preferred white as the office color and believed it would facilitate their office performance. This preference for a white office might be due more to the cultural expectation for a white office as opposed to a performance-based selection.

The difference in perception and preference between females and males was also reflected in these studies, as the findings suggest that the color characteristics or degree of brightness of a room might affect males and females differently in our culture.

Finally, an individual’s screening ability may influence how people are affected and perform in a particular interior. This can be an important guide for designing a productive office interior. The individual screening ability should be examined more closely by employers and designers so that the office design can be better tailored to occupants’ characteristics. However, designing an interior space for individuals with different characteristics may be difficult, if not impossible. Thus, designers should strive for universal design with maximum flexibility that allows for personal control within the same general space to better fit each individual occupant.
Glossary

EPI: The Eysenck Personality Inventory is a questionnaire designed to measure two major dimensions of personality, namely extraversion and neuroticism.

ESQ: The Employee Screening Questionnaire predicts subjects’ likelihood of engaging in several positive and negative work behaviors and provides a profile over eight categories: anxiety, stress, depression, regression, fatigue, guilt, extroversion, and arousal.

ICBT: The Ishihara Color Blindness Test is a test for red-green color deficiencies. It was named after its designer, Dr. Shinobu Ishihara, a professor at the University of Tokyo, who first published his tests in 1917.

JAS: The Jenkins Activity Survey was developed in an attempt to duplicate the clinical assessment of the Type A behavior pattern by employing an objective psychometric procedure. Individuals displaying a Type A behavior pattern are characterized by extremes of competitiveness, striving for achievement and personal recognition, aggressiveness, haste, impatience, explosiveness and loudness in speech, characteristics which the JAS attempts to measure.

MCT: The Minnesota Clerical Test was introduced in 1931. Since then, employers have been utilizing it to measure clerical skills, perceptual speed and accuracy, for different clerical jobs.

Munsell: The Munsell color system is a system that specifies colors based on three dimensions of color: hue, value (lightness), and chroma (color purity or saturation). Professor Albert H. Munsell created it in the first decade of the 20th century.

POMS: The Profile of Mood States questionnaire is a 65-item instrument that assesses a person’s moods—e.g., anger, anxiety, confusion, depression, fatigue, vigor.

SSQ: The Mehrabian Stimulus Screening Questionnaire measures the individual differences in automatic screening of and habituation to irrelevant stimuli. Low screeners are individuals, who cannot screen a lot of incoming sensory information.

Notes


Further Reading


Biography

Nancy Kwallek earned her Ph.D. at Purdue University in Environmental Design & Housing. Dr. Nancy Kwallek is Director of the Interior Design Program in the School of Architecture at The University of Texas at Austin. She holds the Gene Edward Mikeska Endowed Chair for Interior Design and is a Registered Interior Designer in the state of Texas. For over the last twenty years, her research has examined human response to the interior ambience of office environments where focus is placed on worker mood, productivity, health, well-being, performance, and satisfaction of workers. Several phases of research have involved subjects working on office tasks in confined spaces in a variety of office color palettes. Recognized as an international expert on the effects of interior color on humans, Dr. Kwallek has presented juried, invited, and plenary papers on her research to international scholarly, design, and professional groups on five continents. Currently she is developing an extensive project to test the effects and interrelationships between color, indoor air quality (IAQ), and off-gassing of various materials including reprocessed and recycled materials compared with nontoxic natural ‘green’ materials. She is preparing to study the effects of off-gassing and IAQ on office workers within a confined interior space.