The Logistical Stimulation of Color

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ABSTRACT

Color psychology has been mainly researched for its stimulus in regards to marketing and emotions. This study found a notable lack of research regarding color's stimulation of mental activity. Consequently, the problem at hand is determining color stimuli's effect on test scores regarding logistical performance. The goals of this study are finding how environmental factors, such as color, may stimulate the brain. Using a true experimental design, the study manipulated the single variable: color stimulants (these are green, red, white, and blue). This method provided valuable information in that green is a significantly superior stimulant than red, blue, or white. Therefore, it would be beneficial to student learning if classroom environments utilized green color stimulants, and avoided red color stimulants. Furthermore, this idea that color can stimulate mental activity is beneficial for the development of color therapy.

KEYWORDS

Behavioral and Social Sciences 1, Psychology 2, Color Psychology 3, Color Stimulants 4, Mental effects 5, Heliotherapy 6, History of Color 7

INTRODUCTION

Everyday, the human retina is absorbing light waves that translate into the brain as roughly one-million different colors and shades; however, this common phenomenon is more than just visual input, as it influences a person's emotional, biological, and mental responses.

The History of Color

Sir Isaac Newton is credited with beginning some of the first experiments with light rays and the color spectrum, discovering that white or visible light was made of seven different colors, known as ROYGBIV (The Science of Color, 1970). Then, advancements in the study of color continued in the late 18th century when Thomas Young realized that the same three colors could be used to create all other colors. He theorized that the 'primary' colors, red, blue, and green, were the only colors that could actually be seen by human eyes. All other colors were mixtures of the three, notated as 'secondary' or 'tertiary' colors. Young's theory of primary and secondary colors was rejected in his time, but later rediscovered by a scientist named Hermann von Helmholtz. After its rediscovery, the Young-Helmholtz Theory, as it was named, was applied in ophthalmology. It was supported by the idea that the retina held only three nerve fibers and not one for each color (for example, there is no O fiber, but orange can be detected by G and R fibers) (Boring, 1942). The Young-Helmholtz Theory was disputed throughout the 19th century, but it gave way to countless studies, theories, and research that sparked the evolution of color theory into color psychology.

However, these were not the first experiments with color. Ancient civilizations regarded sunlight and different colors as forms of medicine and healing (Saunas, 2019). For example, the Ancient Greek and Egyptian civilizations practiced their own form of Heliotherapy and Chromotherapy, respectively. These cultures both believed that the sun's rays were a healing gift from the gods. Both civilizations were recorded to have built special rooms that refracted the Sun's rays through a prism to isolate different colors. Certain rooms held a specific color that was used for different ailments. Furthermore, Ancient Chinese and Indian medicines associated different parts of the body with different colors, known as

the 5 Elements of Chinese Medicine and the 7 Chakras. Each believed that the unnatural presence of one of these colors could identify illnesses. Both of these practices were used for healing organs and promoting positive mental and spiritual health (2019).

This idea of visible light being used in medicinal practices has been prevalent across many ancient civilizations (Saunas, 2019). In fact, research in this discipline has continued into the modern era. Studies involving the electromagnetic radiation of visible light and its effect on diseases, ailments, etc are still being conducted. One study by Azeemi and Raza (2005) identified the history of chromotherapy in ancient civilizations and compared that to current research by Pakistani scholars. While this form of therapy is still in development, it may prove beneficial to identify the mental stimulation of colors for psychiatric purposes.

The Implications of Colors

Denoting a specific meaning for one color can be difficult as there are positive and negative meanings behind each color and there are cultural differences amongst one's response. For example, in Western cultures, black symbolizes death, where in some Eastern cultures, white symbolizes death (Batagoda 2018). This paper will focus on Western implications, as that is the most popular culture amongst the subjects.

Red - In the positive aspect, red is associated with love, passion, and energy. This is partly due to the common use of shades of reds in romantic settings (i.e. Valentine's Day). In the negative aspect, red is associated with danger, aggression, and power (Cherry, 2020). This is due to its longer wavelength that makes the color more noticeable to warn people of danger (ie stop signs). In a biological aspect, red or shades of red have been found to elevate blood pressure, enhance metabolism, and increase heart rate (AL-Ayash, Kane, Smith, & Green-Armytage, 2015). The physical response to colors may also explain the color's association with certain emotions, as one's heart rate may elevate during times of romance or anger.

Orange, Yellow - Yellow is a bright color which grabs attention. It can invoke feelings of happiness in smaller exposures and feelings of annoyances in larger exposures. On a biological level, yellow has been found to generate muscle energy

(Braam, 2021). The greater production of energy can explain why yellow has been reported as a warmer color and a stimulus of mental activity. Orange is a mixture of two primary colors, red and yellow, and its implications are noted as a mixture of the two.

Green - Green greatly opposes the effects of red, likely because it is opposite to red on the color wheel. Green is associated with wealth, nature, and tranquility. The association with nature creates a calming effect that slows the heart rate and metabolism (Braam, 2021).

Blue, Purple - In a more positive aspect, blue evokes feelings of calmness and productivity. In contrast, blue may also evoke feelings of sadness. In a biological aspect, blue lowers the pulse rate and body temperature and decreases one's appetite (Cherry, 2020). The decrease in appetite can be helpful to weight loss programs. The appetite loss is likely because of the instinctual response that blue in foods is unnatural or poisonous. Purple is a mixture of two primary colors, red and blue, and its implications are noted as a mixture of the two. However, in Western cultures, purple is also associated with royalty/nobility and spirituality (Braam, 2021).

White, Black - Black is associated with fear, death, and elegance. It is usually associated with evil and/or mysterious figures. White, on the other hand, is a light color that is typically associated with innocence, purity, and cleanliness (Braam, 2021). These colors are typically opposites in connotation as one absorbs the whole color spectrum and the other reflects the whole color spectrum.

Relevance Today

Multitudes of studies have been performed regarding color's stimulation of emotions. One study by Kurt and Osueke (2014), found that certain shades/colors on the walls of dorm buildings inspired different emotional effects in college students. For example, cooler-neutral colors resulted in more calming emotions amongst the college students (Kurt & Osueke, 2014). Many of the emotional-analysis studies resulted in similar data collected. This was beneficial information, as the studies concluded that the symbolic implications regarding color can directly affect emotional response, information that was regarded when

selecting color stimulants for this research paper.

Returning to recent physical studies, the Olympic Uniform Study (2004) found that athletes who competed in fighting sports, such as wrestling, boxing, or martial arts, were 60% more likely to win their matches if they were wearing the color red (Belluck, 2009). The study highlights the biological stimulation of the color red, which increases one's heart rate and attention of the combatant, while psychologically intimidating their opponents. Another study on color's physical stimulating properties was by Woods and Spence: "Using Single Colors and Color Pairs to Communicate Basic Tastes". The study found that certain colors stimulate certain taste buds more than others. Based on a food's color, one's taste receptors would respond differently to the same flavor of a different color (Woods & Spence, 2016). For example, black foods stimulate the bitter receptors more than the salty, sweet, or sour receptors.

However, in this discipline there is a notable lack of studies regarding color's effect on mental capabilities. One study by Olurinola & Tayo aims to evaluate the effects of color on memory, discovering that color associations can improve the memory and purposeful color contrasts can negatively affect memory (2015). Color's effect on memory was a common study found during research. Other mental abilities, such as aptitude, stress, or brain function, were not widely tested. Therefore, this study proposes the question of the extent of color stimuli's influence on a human's mental, specifically logistical, performance. The following study was based mostly on the subject of a study done in the *Journal of Family and Consumer Sciences Education* that evaluated the colors of elementary school classrooms and compared those with classroom grades and mood/behavior (Gaines and Curry, 2011). In contrast, however, this research paper aims to fill a gap pertaining to high school students instead of elementary students and is focusing specifically on the effects on aptitude test scores instead of observational studies.

Need For the Research

This study aims to answer the question: What are the effects of different color stimuli on test scores regarding logistical

performance of high school students? The goal in this is to evaluate potential links between four chosen color stimuli and the logistical performances of the subjects. The methodology of this study consists of four questionnaires that differ only in the colored background, acting as the color stimuli for this study. Each questionnaire consists of the same ten multiple choice questions relating to aptitude and one short-answer question asking for the color the subject sees and any visual impairments. The questionnaires were sent out to the high school student body in an email and were distributed based on one's birth month (not to test birth month, but to ensure a more equal distribution of subjects-to-tests). Furthermore, the remainder of this paper will be divided into five main sections: *Methodology*, *Results and Findings, Discussion, Limitations and Future Research, and Conclusion*.

The following research focuses within the discipline of color psychology to determine how four different color stimuli may affect the scores of logistical performance exams taken by Florida high school students. The goals of the project are understanding how certain environmental factors, specifically color, may stimulate the brain. With this information, academia may be altered for the better, as students and teachers would have new methods to stimulate classroom learning. Also, society would have more knowledge regarding how color can influence mental activity, which could aid in the development of color therapy, helping patients with both physical and mental disparities.

METHODOLOGY

Study Design and Method

This study used a true experimental research method. A true experimental design allowed the research to specifically focus on the chosen hues and to isolate the stimulus to note the effects of aptitude only (as opposed to physical/emotional performance). This method had no control over any other variables besides the color stimulants, so outside factors were accounted for but not controlled. Other outside factors were more limited when utilizing this method. The research did not have to interpret or isolate what could have been an influence from audio input, for example, and it solely focused on the independent and dependent variables. The variable being manipulated,

or the independent variable, was the individual subjects' color stimuli. And, through the true experimental design, the effect this variable did or did not have on the subjects' aptitude results could be easily identified as the dependent variable.

Hypothesis

After extensive research, the study believes that the most likely conclusion will be as follows: Green will prove to be a positive color stimulant on logistical thinking, and Blue and Red will prove to be negative color stimulants on logistical thinking. However, only the results will determine whether this hypothesis is supported or not.

Consent and Confidentiality

Informed consent was taken from each of the respondents for data collection. Confidentiality and privacy of the respondents were maintained, as no data would be disclosed to a third party. No identifiers such as name, emails, or pictures were disclosed in the article or while conducting the study. Ethical guidelines of research were followed.

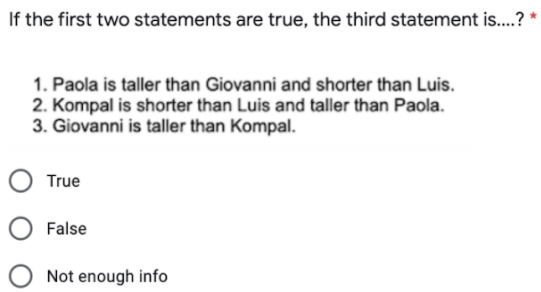
Sample

The subjects were volunteer students who took the performance test. These individuals consisted of 110 Florida high school students (grades 9-12). This would include teenagers from ages 14 to 19. These subjects were utilized to test a certain demographic not as commonly studied within this discipline: high schoolers. Current research performed tests regarding emotional responses of elementary students and college students, but none pertained to the demographic of high schoolers, who are in the prime of their development. Also, the information being collected pertains to a learning environment, which would give a reason for choosing students as research subjects. The study gathered prospective subjects by broadcasting research information and the questionnaire to the school emails of students. Through this, the volunteers were acquired.

Tools Used

The instruments used in the study were the test and the color stimuli. The color stimuli consisted of the background screen of the questionnaire document. The color stimuli were attached to the study's test document so that the subjects could not discard the

stimuli and invalidate the results. The test was formulated to calculate differences in logistical performance amongst the subjects and their group's stimulant. The questions provided consisted of analogies (mathematical and verbal), pattern recognition, visual interpretation, spatial recognition, and logical reasoning. There were two analogy questions, three pattern recognition questions, two visual interpretation questions, one spatial recognition questions, and two logical reasoning questions. These specific types of questions were chosen as they pertain to thinking involving the frontal lobe, or the logistical part of the brain. Also, the study's examination of other types of aptitude tests found that these five types of questions were the most frequent. In order to analyze the results, questions were graded on a point scale and averages of each correct answer of the color stimuli groups were taken. Finally, an 11th question was added asking the participants what color they saw and any visual impairments they would like to notate. A copy of all of the test questions and their classifications are located in the Appendix.



An example of a provided analogous test question (all test questions and their classifications are in the Appendix).

Data Collection Procedure

First, the study consulted other online aptitude tests to determine the appropriate question types for the research project. Based on this research, the questionnaire was created. Next, high school students were sent an email with information about the study and the option to complete the questionnaire. No time limit was supplied. Each subject received the same test pertaining to logistical performance in one of four color stimuli: red, green, blue, and white. The students were instructed to pick the test in accordance with their birth month (Jan-Mar was red, Apr-June was green, July-Sep was blue, and Oct-Dec was white). This was done to assure a more even distribution of subjects, not test differences in birth month. There were a total of 11

questions that the subjects were required to answer. Ten questions were the analogies (mathematical and verbal), pattern recognition, visual interpretation, spatial recognition, and logical reasoning type questions. The 11th question asked the subjects to record their color stimulant and any visual impairments they would like to notate. This was done to examine any visual inconsistencies amongst the subjects/groups in the study. A total of 110 students took the test, with 22 in the green color stimulus group, 29 in the white stimulus group, 28 in the blue stimulus group, and 31 in the red stimulus group. Then, the study sorted and organized the collected responses per the four color stimuli groups. It calculated medians, means, and modes of percentage correct (for each individual question and overall). This data was visually represented in a table and a bar graph. Finally, T-tests for each color group pairing were performed.

RESULTS AND DISCUSSION

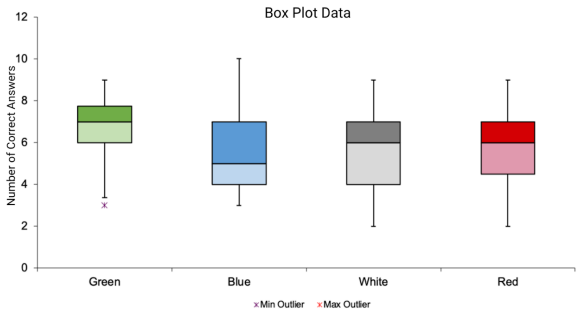


Figure 1: A box plot graph of each color stimulant's "correct answer" data.

For each individual question, Google Forms supplied a percentage of subjects who answered correctly. Averaging those results, the "Green Stimulant" had a correct answer rate of 70.45%, the "Blue Stimulant" had a correct answer rate of 57.15%, the "White Stimulant" had a correct answer rate of 63.80%, and the "Red Stimulant" had a correct answer rate of 54.85%. The stimulant groups had correct answer medians of seven, five, six, and six, respectively. Using a statistics program, the research created a box plot of the data of correct answers, including minimum/maximum outliers. Figure 1 shows boxplots of the maximum and minimum values in the data, the medians, and the range of 25th to 75th percentile (as represented by the boxes). Furthermore,

only one outlier was found. Within the Green Stimulant, there was one minimum outlier of a correct answer score of three.

A T-test was performed for each of the six color pairings (i.e., Green compared to White) to evaluate the significance of the findings. The significance level is the probability of rejecting the null hypothesis. For example, a significance level of 0.05 indicates a five percent risk of concluding that a difference exists when there is no actual difference. The Green-Blue test revealed a 12.24% risk, the Green-White test revealed a 15.01% risk, and the Green-Red test revealed a five point eleven percent risk. However, there was only a risk of one point seventy three percent when the minimum outlier was removed. Furthermore, the Blue-Red test revealed a 93.10% risk, the Blue-White test revealed a 72.96% risk, and the Red-White test revealed a 65.47% risk. All of this data is organized into Table 1.

T-Test Percentage Results	Green	Blue	White	Red
Red	5.11% (without outlier: 1.73%)	93.10%	65.47%	N/A
White	15.01%	72.96%	N/A	65.47%
Blue	12.24%	N/A	72.96%	93.10%
Green	N/A	12.24%	15.01%	5.11% (without outlier: 1.73%)

Table 1: Shows the percentage of risk of all possible two-color pairings. The Green-Red Test included the percentages with and without the inclusion of the outlier.

22 subjects responded to the “Green Stimulant” test (20% of all respondents). The technical color hue on the hex scale was #afdfa6: a lighter shade of green. Twenty-one of the subjects reported seeing a color around this shade, with reports of “green, pastel mint green, light green, key lime pie green, mint green, pale shamrock green, matcha green, seafoam green, or dark mint”. Subject 11, however, reported seeing

“white”. No visual impairments were mentioned amongst any of the “Green Stimuli” subjects.

28 subjects responded to the “Blue Stimulant” test (about 25.45% of all respondents). The technical color hue on the hex scale was #c8b3ff: a lighter shade of blue. However, 27 subjects mentioned seeing shades of purple, with reports of “purple, light purple, lavender, lilac, periwinkle, violet, pastel purple/indigo, or purple-blue”. Subject 23 is the only to report a shade of blue, saying “baby blue”. Only two subjects reported any kind of visual impairments, Subject 6 mentioned “mild color blindness” and Subject 19 mentioned “nearsightedness”, who saw purple and light purple, respectively.

29 subjects responded to the “White Stimulant” test (about 26.36% of all respondents). The technical color hue on the hex scale was #f6f6f6: a darker shade of white. A majority of the subjects reported seeing similar shades, with reports of “white, light grey, gray, grey-white, eggshell white, and light beige”. However, there were two color inconsistencies, Subject 11 had their devices on dark mode and saw a “black” stimulant, and Subject 16 reported seeing “light blue mix with a little bit of purple or grey”. Only two subjects reported visual impairments (not 11 or 16), Subject 5 reported needing to “wear glasses due to the fact that I can barely focus on what’s a foot in front of me” and Subject 24 reported “severe Deuteranopia”, who saw light grey and white respectively.

31 subjects responded to the “Red Stimulant” test (about 28.18% of all respondents). The technical color hue on the hex scale was #ffa6a6: a lighter shade of red. A majority of the subjects reported seeing similar shades, with reports of “pale/light red, pink, salmon, rose, peach, coral, pink-orange, and yellow-ish pink”. Only two subjects reported visual impairments, Subject 17 reported needing to wear “blue light blocking glasses” and Subject 23 reported having “deutan color blindness”, who said they saw light red/pink and salmon respectively.

Referring to the initial question - What are the effects of different color stimuli on test scores regarding logistical performance of high school students? - the information has provided suggestive results.

The research's original hypothesis, based on pre-existing data, assumed that Green would be a significantly superior stimulant compared to any of the other colors. This is because the color green had calming effects that could lower heart rate, a biological response similar to clear headedness and focus (Braam, 2021). However, this was not the case, as the data revealed a significance only between the Green and Red Stimulant groups.

Overall, it was discovered that subjects in the Green Stimulant group scored higher, on average, than any other group. This group had both the highest performing median and the smallest range of 25th to 75th percentile, meaning that 50% of the subjects scored 6-8 out of 10 points. Furthermore, after performing the T-tests for each color pairing, the data revealed that only some of the differences in scores were significant. The difference between the Green Stimulant and the Red Stimulant found a very low probability (5.11%; $p=0.05$) of rejecting the null hypothesis, meaning the difference in performance was significant. Moreover, with the elimination of the minimum outlier, which is not representative of the Green Stimulant data, the probability of rejecting the null hypothesis lowered to one point seventy three percent ($p<0.05$). This suggests that, in the absence of the outlier, the difference between the Green Stimulant and Red Stimulant is highly significant. The outlier suggests that the specific data point is significantly different from the data in that section. Meaning it is likely there was an error during this one test. Both the Green-Blue test and the Green-White test revealed that the significance was in the 80-90% confidence interval. The trend in these two pairings may conclude to be truly significant if more subjects are tested. Furthermore, since the Green group had a larger sample size than any other group, it may prove beneficial to increase the sample size of the other color stimulant groups in order to receive more conclusive results. Despite this, Green was found to be a better logistical stimulant of the four colors that were tested and would be beneficial in boosting mental function and educational performance.

Moreover, the difference between the Red Stimulant and the Blue Stimulant found a very high probability (93.10%) of rejecting the null hypothesis, meaning the results

from these two stimulants were nearly equivalent. Both the Blue-White test and the Red-White test revealed that the probability of differences in these tests due to chance is between 25% and 35%. This suggests that the probability of coincidence in data numbers is great. The Red Stimulant and Blue Stimulant had very similar effects on the subjects in regards to logistical performance, with little notable differences. Both the Red and Blue Stimulants appeared to underperform when compared to the Control (White Stimulant). However, further study is needed to reinforce this analysis. Compared to Green, Red and Blue stimulants were found to be a worse logistical stimulant, and therefore, should be avoided in the classroom setting.

There were no surprising results besides reports of color observed in the Blue Stimulant group. Majority of the subjects noted seeing shades of purple, with only one actually seeing a shade of blue. It is possible that the results found were not conclusive to a true blue stimulant, since the effects are based on the viewer's perception. However, blue and purple are close on the color wheel and have similar biological/symbolic effects (Braam, 2021). The only difference would be the greater tones of red in the purple stimulant than the blue. Moreover, this research found no real significant difference between the Blue Stimulant and the Red Stimulant, which could be explained by the viewers' perceptions of the extra red tones in the Blue Stimulant category.

Furthermore, this topic of color's influence on the human mind deserves more research/study. Some suggestions for future research would be analyzing the effects of different color stimulants on subjects with color vision deficiencies. It would be interesting to determine how the altered view of certain shades/pigments can lead to different biological, emotional, or mental responses compared to a subject without color vision deficiency. To continue, notating differences between genders' responses to color would be another possible field of study as there are notable evolutionary differences involving gender and color shades.

LIMITATIONS

It's hard to determine whether some stimuli were more effective. The first possible limitation of this study would be its small sample size. Each color stimulant group had only between 22-31 responses (averaging 27.5 responses). The T-tests only found a significance between the Green stimulant results and the other three color stimulant results. With more subjects in each group, the T-test between the other color stimulants (ie. Red and Blue) could have revealed a possible significance or greater certainty of a lack of significance. The second possible limitation of this study is human error, as is the case with using human subjects. The study was personally contacted by anonymous test subjects explaining how they took multiple tests by accident, had software that altered the appearance of their screen, or were under the influence of other variables during the test. Outside factors the study had no control over may have caused some inconsistencies.

CONCLUSION

In conclusion, color stimulants can be used to boost mental function. The inquiry within this research process was successful in its choice of color stimulants, as they provided a variety of biological and psychological/emotional responses. Both past and current research explain how different colors may affect biology, including changes in heart rate and metabolism (AL-Ayash, Kane, Smith, & Green-Armytage, 2015). Using the context of current research, one can begin to understand the extent of color's effects on the human body and brain. For example, research on the physical effects of color supports this report's findings that Green was a significantly better logistical stimulant than Red. However, further inquiry is needed to fully understand the significance or lack of significance between other stimulants. Moreover, the findings of this study, paired with current information in the field of color psychology, can have significant contributions to society's body of knowledge. Continuous research into the effects and stimulant properties of different colors can be beneficial in a classroom setting. Students and teachers can better use

this knowledge for studying, boosting attention in class, etc. Beyond the educational environment, this information could be utilized in therapy. Color therapy is still being researched and developed, but the knowledge that color can act as a mental stimulant could aid this process to help people cope with mental blocks or disabilities.

ACKNOWLEDGEMENTS

I would like to acknowledge the psychology teacher at my school, Ms. Berben, who aided in the development of my method to accurately gather data without too many outside factors. I would also like to acknowledge my teacher, Ms. Schuh. She kept me inspired to research and complete this project on time

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