Physiological response to color variation as measured through Galvanic skin response, electrocardiography and electroencephalography

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Human Physiology 435
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Key Points Summary

- The body's parasympathetic response is characterized by a decrease in heart rate, Galvanic skin response, and brainwave activity while the sympathetic response elicits the opposite effects.
- Color has provided natural warnings to animals since evolution began.
- We seek to demonstrate that the body's response on exposure to blue will reflect a parasympathetic response and exposure to magenta will reflect a sympathetic response.
- Data analysis reveals that heart rate and GSR were slightly increased when looking at magenta compared to exposure to blue but no physiological response occurred in regards to brain activity.

Word Count: 2,567

Abstract

Color is an important facet of daily living and a crucial evolutionary adaptation. It can be linked to a myriad of emotional responses, ranging from calming to stimulating. We hypothesized that participants exposed to the color blue would have their body physiology shift to a parasympathetic dominant state, while exposure to magenta would yield a more sympathetic dominant state. Electroencephalography (EEG), Galvanic skin response (GSR), and electrocardiography (ECG) were used to gather data from 22 college-aged participants exposed to a blue color, followed by a magenta color. The gathered GSR data supported our hypothesis, as an average increase in heart rate and skin conductance was observed amongst test subjects upon seeing magenta following the blue color. However, statistical analysis of EEG data did not reveal any significant difference in brainwave activity with color variation and no correlation between GSR and EEG data was observed. We suggest future research on this subject to be conducted under tightly controlled environmental conditions with an emphasis placed on the maintenance of constant light intensity.

Abbreviations

- EEG, electroencephalography
- ECG, electrocardiography
- GSR, Galvanic skin response

Introduction

Color plays an influential role in our everyday lives. Created from different wavelengths of electromagnetic radiation, colors come in an infinite number of shades and combinations. Humans find color pleasing, developing preferences and utilizing color as markers of self-identification. Colors characterize nature, works of art and other manifestations of beauty. It has been established that humans have an emotional response to colors, often associated with objects or memories (1). This emotional response is cross-culturally dynamic and often variable; but there exists a fundamental commonality to the relationship between color and emotion, which is considered to be universal, breaching the lines of geography and race (2). For example, the color blue is the most frequently incorporated color in marketing strategies in the U.S. On the other side of the world, the inhabitants of East Asian countries associate this color with evil and cold, but to the residents of the Netherlands, blue represents warmth (3). However, less research has been done on the physical response to color, and it has yet to be conclusively determined whether humans respond to color in a specific physiological way.

Evolutionary biology suggests that color may be ingrained into the human psyche (4). Typically bright colors such as shades of red, orange, and yellow are considered dangerous in nature. Animals and plants employ bright pigmentation to caution predators that they are

potentially poisonous or otherwise hazardous to consume. One potent example in nature can be found in the family *Dendrobatidae*: the poison dart frog. Studies have been performed which exemplify the relationship between the frogs' color and the level of their toxicity (5). By comparing the phylogenetic background of the *Dendrobatidae* family, scientists were able to establish the parallel nature of the evolution of toxicity and bright color patterns (6). Entire systems of Batesian and Mullerian mimicry have been adapted by animal species focused around this warning by color (7). In contrast, soft or muted colors indicated the opposite response. There is no clear danger signal for these colors; in fact, "softer" colors are believed to be calming and sedative (8). It is possible that such emotional valences of danger/calm may be linked to the corresponding physiological sympathetic and parasympathetic body states.

The primary purpose of our research is to explore whether or not there is a measurable physiological change between sympathetic and parasympathetic states associated with the observation of bright versus calming colors. The sympathetic body state is more commonly known as the "fight or flight" response and is characterized by increased blood flow to muscles, dilation of pupils, increased heart rate, and increased blood pressure (9). A parasympathetic body state is present when the body is "resting and digesting." Physiological properties of a parasympathetic state are increased blood flow to the internal organs, reduced blood pressure, and reduced heart rate (9). Galvanic skin response and heart rate values of our subjects will be analyzed in order to determine the presence of one state or the other. These physiological measurements were chosen as they allow for the accurate determination of a body's current predominance between sympathetic and parasympathetic physiological states. We expect subjects to yield a parasympathetic response determined by low skin conductance and lowered heart rate upon exposure to blue, a mild color; conversely, upon exposure to visually offensive magenta, we anticipate a sympathetic physiological response which will be correlated to increased skin conductance, and increased heart rate. The secondary purpose of our research is to search for a correlation between the parasympathetic versus sympathetic states of the body and the existence of specific brain wave patterns in each state. We hypothesize that the sympathetic state created by observation of the color magenta will be associated with increased EEG brainwave frequency whereas the parasympathetic state associated with observation of the color blue will yield a decrease in the frequency of EEG waves.

Methods

Test subjects included 11 female and 11 male undergraduate and graduate students from the University of Wisconsin - Madison. Each subject was asked to sign a liability consent form and was given a brief outline of the proceedings of the experiment without identifying which colors would be used in the experiment.

The Galvanic skin response was measured utilizing the Biopac Student Lab - L09 Galvanic Skin Response & Polygraph. A pair of electrodes was attached to the middle and index fingers of the right hand. Heart rate was monitored with the Biopac Student Lab - L09 Galvanic Skin Response & Polygraph by attaching electrodes to the inner right wrist and the insides of the two ankles. EEG waves were measured with the Biopac Student Lab - L03 EEGI by attaching electrodes to the right earlobe, directly above the right ear, and behind the right ear. Once the electrodes were attached, a swim cap was placed over the subject's head to secure the connection of the electrodes.

After all data collecting devices were connected to the test subject and calibrated, the following experimental protocol was followed while continuously recording from the devices: test subjects were asked to look at a series of poster boards of black, blue, and magenta colors placed in a location to yield complete immersion of the visual field. The subjects were instructed to relax and concentrate only on the color presented for a thirty second time interval. Colors were presented in the order and time intervals presented in Figure 1.

In between every color transition, the test subject was asked to close their eyes for fifteen seconds. When the examiner told the subject to open their eyes, the recorder made a designation mark on the computer program to determine the time at which the subject responded to command prompts.

Data was analyzed by comparing mean alpha and beta wave amplitude of EEG, heart rate

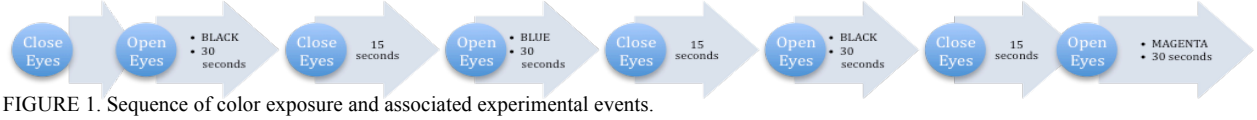

FIGURE 1. Sequence of color exposure and associated experimental events.

(beats per minute) and mean Galvanic Skin Response (microsiemens) values between measurements taken during stimulation by magenta and blue. Statistical analysis of EEG data was performed by measuring the amplitude of alpha and beta waves of each individual. In order to determine the statistical significance of the EEG data, each participant's file was analyzed for the mean amplitude of the alpha and beta waves. The data was highlighted two seconds before and four seconds after the indicated color change for a total of a six second interval; this interval was used to compare the brain's initial interpretation of the color exposure. By using a ratio of beta wave over alpha wave mean amplitude, it was expected that the value computed during magenta exposure would be larger than that corresponding to blue exposure. Using the paired T-test for significance, the p-value was computed and compared to the 95% confidence interval.

Results

Electrocardiogram and Galvanic Skin Response

Heart rate via ECG was observed for all subjects. Once the subjects were seated and electrodes attached, resting heart rate was established. Subjects were monitored throughout the entirety of the experiment. Average heart rate after exposure to blue and magenta was calculated, as well as the maximum heart rate during the same periods of exposure. Average heart rate among participants was observed to be higher during exposure to magenta versus blue (Figure 2), proving to be consistent with our expected outcome.

GSR was simultaneously observed throughout the session. Participants' skin conductance was scrutinized two seconds before color exposure and ten seconds after exposure, totaling twelve seconds. Average GSR response to blue was considerably lower than magenta values, as depicted by Figure 3, and correlates to our expected outcome regarding increased sympathetic response.

Electroencephalography

We analyzed the results of the participants' EEG measurements by comparing the mean amplitude of beta wave over alpha wave during magenta to the ratio during blue. Table 1 shows the mean amplitude values. Over half the subjects showed a higher ratio of beta to alpha wave mean amplitude when exposed to magenta following exposure to blue. However, according to the paired T-Test, the p-value was computed to be 0.4797. Because this is considerably higher than the significance level of 0.05, we do not reject the null hypothesis; therefore, there is no significant autonomic brain activity in response to color.

Discussion

The average maximum GSR values showed an overall increase in skin conductance when subjects were shown a blue color followed by a bright magenta color. This increase in skin conductance is indicative of a more sympathetic physiological state and would be expected upon arousal of the subject. Our results indicate that the subjects were more aroused by the magenta than by the blue color. However, it could not be determined whether or not the blue color had the opposite effect of triggering a more relaxed, and thus parasympathetic dominant state, in our subjects. Though subject color preference was collected post-examination period, there was no observable correlation between preference and brainwave outcome. In future studies, we suggest such data be obtained by initially placing subjects in an aroused state and then presenting them with the blue color to see if a parasympathetic response is triggered. A measure of mean arterial blood pressure (MABP) throughout the study would also be helpful in further experimentation. This additional data would aid in the determination of a subject's dominant autonomic nervous state at a given time, and coupled with GSR data would strengthen our results.

To obtain the mean amplitude, we took a measurement of two seconds before and four seconds after the color change. This six-second range was chosen in order to examine the brain's activity when the participant was first exposed to a new color. It was important to account for slight variations between when the participant opened their eyes and when the EEG recording was marked with this event. By allowing a few seconds on either side, it was possible to include the point when they opened their eyes and saw the color. Two additional seconds were added to the latter half of the measurement because we wanted to accurately reflect the participants' brainwave reaction to the new color: more time after their eyes were opened allowed us to focus on the brain's response.

Because we expected the beta wave EEG activity during exposure to magenta to be greater than during exposure to blue, we took the beta wave mean amplitude over the alpha wave mean amplitude, anticipating a larger value corresponding to magenta. Twelve of the twenty-two participants exhibited a larger beta-to-alpha ratio during magenta when compared to the frequency of brainwave activity when exposed to blue.

We sought to reject the null hypothesis that there would be no change between exposures to blue compared to magenta. Because there were 22 subjects, there were 21 degrees of freedom between trials. The average and standard deviations were computed and used to find the test statistic, which was then used to find the p-value. Although a slight majority of the participants showed an increase in beta wave brain activity during magenta, the statistical analysis indicates that this majority does not correspond to a significant increase in sympathetic brain signals during magenta.

Following session completion, subjects were also asked what their favorite color was following the experiment. This was done in order to allow for a possible explanation of situations where blue yielded a stronger GSR/EEG/HR response than magenta, thus going against our initial hypothesis. Out of 9 negative responses, meaning the subject was moved into a more aroused state by presentation of blue color instead of magenta, 5 of the subjects noted blue as their favorite color. The other 4 negative responses had a mixture of favorite colors that included red, pink, green, and none.

Inconsistencies in the data may have occurred through a variety of mechanisms. The machinery used to measure skin conductance (GSR) often yielded inconsistent readings and may have allowed for incorrect variation in the measured skin conductance values between subjects. Variables that may have altered skin conductance transduction, such as hand lotion and dirt on the fingers, were taken into account and were controlled for via use of an alcohol swab prior to attachment of the GSR transducer. However, any remaining substance on the skin aside from the GSR lotion and normal sweat may have altered proper transduction of the skin conductance value.

A number of negative influences may have impacted our data, namely background noise, peripheral color exposure, and light intensity. Sessions were conducted in a classroom environment and subjects were not provided a noise-cancelling device. We believe this may have impacted our data as surrounding groups were using stationary bicycles and loud, startling noises. In eliminating these distractions, brain wave data would likely have been more authentic and indicative of only color exposure response. While we attempted to enclose the subject's visual field with the presented color, it is likely that subjects were still able to see peripheral influences. Thus, the GSR, ECG, and EEG responses may have been altered by these external factors. In future experiments, we suggest that subjects be exposed to color in a secluded environment free of the aforementioned influences. The influence of light intensity should also be addressed in future studies. We attempted to correct for this variable by closing the window blinds in our lab and surrounding the subject's visual field with our presented color. The color was kept roughly 15 cm away from the subject's nose and curled around the face to enclose the peripheral visual fields. However, even with these measures, an extent of variation in the lab's light intensity is expected, and these variations may have led to inconsistencies in observed GSR and EEG data.

Tables and Figures

Participant	β/α Mean Amplitude Magenta (μV)	β/α Mean Amplitude Blue (μV)	Difference between β/α Amplitude of Magenta & Blue	Participants' Reported Favorite Color
1	-2.0109114	-1.9767064	-0.034205	green
2	-55.625	-0.1589226	-55.466077	blue
3	0.61624204	0.0077951	0.60844694	blue
4	1.6399287	0.27491554	1.36501316	red
5	-0.3471302	-4.8444444	4.4973142	blue
6	-1.6066922	-2.6488066	1.4211441	yellow
7	-3.1631003	-1.8996396	-1.2634607	teal
8	-0.1696658	-13.645833	13.4761675	blue
9	12.5925926	-0.1174089	12.7100015	none
10	-0.0916598	3.48089172	-3.5725515	blue
11	0.4506657	-0.2635223	-0.1871434	green
12	-0.1410365	3.55555556	-3.6965921	blue
13	0.35955056	23.6746988	-23.315148	blue
14	0.59154344	-0.1809205	0.77246381	red
15	-2.3386867	-2.934115	0.59542837	blue
16	0.54676259	0.04912281	0.49763978	red
17	-0.1851079	-1.0547303	0.86962239	blue
18	-0.3248811	-2.5520463	-0.6967651	red
19	0.40271493	-0.0145278	0.41724278	blue
20	-7.4030075	-1.8788332	-5.5241743	pink
21	1.18613139	7.42211055	-6.2359979	purple
22	0.68126386	-0.6677316	1.34899549	purple
AVERAGE	-2.6438521	0.16485915	-2.8087112	-
ST DEV	12.3301598	6.48947542	13.6540983	-

TABLE 1. Participants voluntarily gave their favorite color at the completion of the experiment and the results are listed here. The mean beta-to-alpha amplitudes are listed as they correspond to magenta and to blue. The third column reports the difference between magenta and blue and illustrates whether or not the participants' brains were more active when exposed to magenta (a positive value) compared to exposure to blue (a negative value).

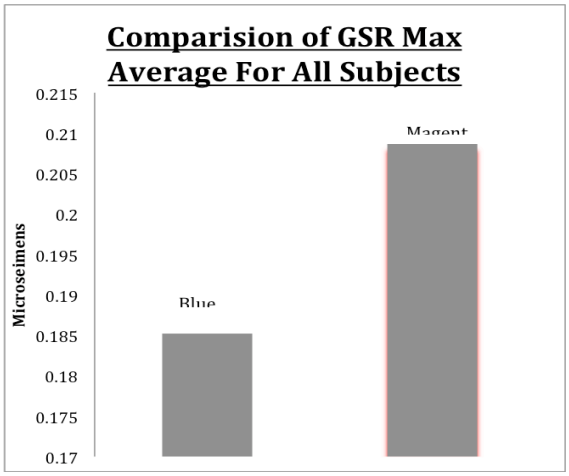

FIGURE 2. The maximum Galvanic Skin Response values recorded upon viewing of blue and magenta colors were taken for all 23 subjects. The values from all subjects were averaged into the average maximum GSR for blue and magenta. These values were then compared and plotted.

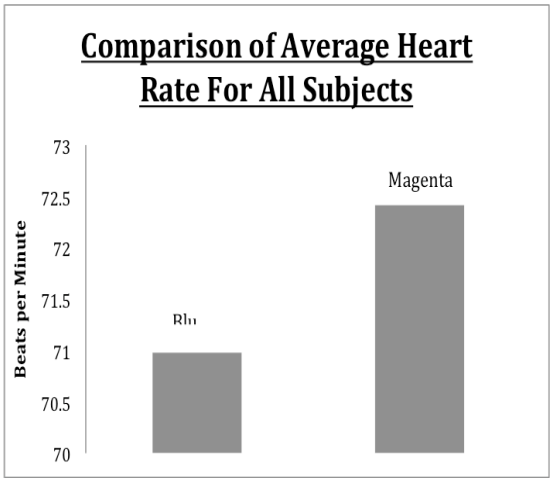

FIGURE 3. The heart rate of each subject was observed over each experimental session. Bars indicate the mean heart rate as captured by the electroencephalography and averaged among participants after exposure to blue and magenta, respectively. Mean heart rate was observed to be 70.97 and 72.41 after exposure to blue and magenta, respectively.

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Author Contributions

Experiments were performed in the Physiology department student laboratory room. K Rahgozar engineered the experimental idea while B Harkonen, K Hokeness, N Kalupa, and K Rahgozar collectively developed the design, data collection, data analysis, and final interpretations. Drafting, revisions, and analysis of intellectual content were also completed by the research team throughout the study period.

The authors hereby collectively confirm that the data presented in this article represents authentic intellectual content as well as approval of its representation.