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Color and Temperature Effects on the Reaction Time of Mental Rotation

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## Abstract

No biological reason has been found to explain the effects color has on people. However, there are psychological theories as to why color affects people's cognitive functions. One theory is that colors affect people by creating a perceived temperature increase or decrease. In order to investigate the idea that the color effects on performance are really temperature effects, a study of the color and temperature effects on the same task was performed. A preliminary study was run in order to determine the perceived temperature of different colors. Colors evaluated at the high, middle, and low ratings were chosen, and corresponding temperatures were used as comparison conditions. Participants were seated in cubicles covered in the designated color at the neutral temperature or the room was in a neutral color at one of the experimental temperatures. The reaction time for participants on a 2-D mental rotation task was reported. Neither the color nor the temperature conditions resulted in a statistically significant difference in reaction time, and neither was there an interaction between the two.

### Color and Temperature Effects on the Reaction Time of Mental Rotation

Stories about the effects of room colors have circulated society for years, ranging from advice to new parents as to what color to paint the new baby's room to studies on what colors may increase productivity ("Light and Color" 2004). However, by examining color receptors and the trichromatic color theory, it is found that color perception is based on the pattern of activity of the short, medium, and long wavelength receptors or cones. Once the stimulus information enters the brain, the only information left for processing is which receptors fired and how strong that firing was. Because the firing of all neurons is the same, all information which would differ between colors is lost. Therefore, there is no biological explanation for a change in behavior. This means that something else must be causing the changes.

Many studies have found an interaction between color and another variable, such as time. An interaction is created two variables work with each other to create an effect on a psychological aspect which was not produced by each variable separately. For example, Etnier and Hardy (1997) found that color and time interacted to increase positive affect and a desire to cope. Narrowing it down, there have been studies showing effects of only color without an interacting variable, but different studies have reported conflicting results. Some showed a large positive effect, some found a large negative effect, and others reported no effect at all. For example, one study found that significantly fewer errors were made in a red office than in a white one. (Kwallek, 1990). While, another study found that in a low demand task in a red partitioned room, errors were much greater than in their blue condition (Stone, 1998). These tests are not identical by any means. The tests use different testing methods which make a difference in their

findings. Also, the colors may not have been the same which definitely could make a difference and make the studies incomparable. Plus, there may be confound variables which can either strengthen or weaken a color effect, or even create an effect not having to do with color that neither study reported. Even with these differences, there must be a reason for the same color seemingly to both increase and decrease the number of errors in the test.

There are some theories about why there are differences in the findings of studies on color effects. Nancy Stone has done extensive research in multiple areas of room color effects. One of her theories is that color affects arousal and fatigue based on the hue. She found that arousal increased in a red room and decreased in a blue room, this caused behavioral differences and a change in the number of errors in her study (Stone 2001). Different levels of arousal can effect tasks in different manners.

Stone (2001) also suggested a relationship between room color and perception of room temperature through a study which found that individuals performing with-in blue partitions perceived the temperature to be cooler than those in the red partitioned workspaces. Still another study found a significant increase in the complaints about the cold in an office which was painted blue after being yellow even though the actual temperature in the office had not changed (Plack & Shick, 1974). By examining these two studies, it is seen that blue, socially known as a cool color, and yellow, known as a warmer color, seem to have an effect on the perceived temperature. From the color choices and effects of the two studies, we may find that there is some psychological effect of the societal labels of warm and cool colors.

Unfortunately, previous research shows a conflict in which colors actually produce a higher perception of warmth and coolness. Dr. Edward Podolsky (1938) found that buffs, pale yellow, tans and flesh colors are suggestive of warmth and that pale red violet and pale yellow green are neutral colors. This goes against our societal beliefs of warm and cool colors, reds, oranges and yellows being warmer and blues, purples and greens being cooler. Plack and Shick (1974) agreed with the social construct when their study found that reds and oranges were the colors which gave a perception of warmth. One reason for this difference may be that their actual room temperatures were different, which led to a perceptual differentiation. While another may have just been due to method differences or differences in color saturation.

Research on actual room temperature differences have shown to effect some of the same human responses as colors, but due to a lack in research there are few studies in either color and temperature research which use similar variables. For instance, reading comprehension was found to decrease in a higher temperature condition (Holmberg, 1969). Stone (2001) found that reading comprehension decreased in a red room, which is socially considered to be a warm color. Heart rates have been sound to significantly increase in warmer temperature conditions (Kudoh, 1991). Heart rates have also been found to increase in red colored conditions (Gerard, 1958). As well as studies that found decreases in reaction time at warmer temperatures (Ramsey, 1978). While another study found that work efficiency is 41% lower at higher temperatures (Abrol 1978). The two previously mentioned studies found that warmer temperatures brought down work rates in manual labor. This finding is similar to Stone's (2001) finding of more errors in a red room in a low demand task, which could include manual labor. Hygge (2001) showed

that there was a better free recall in a cooler temperature than in a warmer one, which differs with Ramsey (1978) who found an increase in short term recall at a warmer temperature. Again, we see that there are discrepancies between the results of these studies. Griffiths and Boyce (1971) make the point that the effects of low thermal differences have been found to be based on the amount of arousal rather than the actual temperature. It may also be the opposite, that they were testing such drastically different temperatures that the studies can't be considered comparable. However, even with the discrepancies, both the color research and the temperature research have found similar human functions to be effected so there may be a relationship between the two. If the two can be compared within the same study a connection between room color and perceived temperature may be seen.

As was shown, the research about this topic is mixed and confusing with no concrete reasoning for color's effect on people's actions or feelings. By sorting out which colors are perceived to be warmer and which are perceived to be cooler, and testing for a perceptual effect, companies, homeowners, and people in general will benefit by knowing which colors will provide greater warmth or coolness in order to counteract nature or other actual physical temperature differences. It is hypothesized that the reason that color has an effect on reaction time (and other aspects of a person's action) is actually due to the perceived increase or decreased in temperature based on the color's hue. Warmer colors and temperatures should result in a lower reaction time and cooler colors and temperatures should result in a higher reaction time.

## Method

### Preliminary Study

A preliminary study was run in order to determine which colors are perceived to be which temperatures. A computer program was set up online which presented a series of full screens of a color to the participants. On the screen of color is a black sliding scale ranging from 0-200. The instructions asked the participants to rate how warm they thought the color was from 0 to 200, 0 being the coolest and 200 being the warmest. Answers were averaged and the top temperature color, the bottom temperature color, and the mid range temperature colors were used in the laboratory study. For internal validity the preliminary study had multiple screens of each color. The results can be seen in Figure 1. The top peak is red meaning it was rated to be the warmest and the bottom peak is blue meaning it was the coolest. The middle color was chosen from among the colors ranked around the 100 level. These were pink, yellow, and green. Green was chosen due to the overlap in perceived temperature between bluer greens and yellower greens. This meant that the paint color didn't have to be exactly what was presented on the screen, if it wasn't available, and the perception of temperature would not have been effected.

### Participants

Participants consisted of 36 students, ages 18-43, from a small Midwestern liberal arts college. There were 10 males and 26 females. All participants could receive extra credit in a psychology class for participating in the study.

### Materials

Once the colors were ranked for warmth, using the preliminary study results, the highest temperature color, middle temperature color, and lowest temperature color were

paired with a high, middle, and low temperature. Large amounts of cardboard and paint, from Wal-Mart, were used to create a colored interior space, the size of an office cubicle. A picture of the set up is shown in Figure 2. There was a Gateway Pentium 4 computer set up with a mental rotation program from Cog Lab on a CD by Wadsworth in each cubicle. A survey containing questions about basic demographic information was used to gather basic information about the subjects, like age and gender. This survey also served the second purpose of giving the condition time to take effect. This gave the participants between 5 and 10 minutes in the environment before they completed the mental rotation task. A temperature controlled room was used for all conditions and the temperature was double checked with a digital thermometer.

### Procedure

The participants were randomly assigned to either a color condition or a temperature condition. In the color conditions, the room temperature was set at 70 degrees Fahrenheit, and in the temperature conditions all cubicles were a neutral color. In all conditions, participants were seated at a computer station. All 4 computers were set up exactly alike, the background was the same. Each participant was asked to answer whether or not the two 2-dimensional images presented on the screen were the same image or mirror images by pressing either s for same and m for mirror. The two images were rotated either 0, 45, 90, or 135 degrees relative to each other. An example of the images presented to the participants is shown in Figure 3. The participant's reaction time to respond was recorded by the computer program.

### Results

Due to the nature of the mental rotation task, the data has been broken between the same and mirror response reaction times because the two types of responses should have a statistically significant difference in reaction time. Data was also condensed across the rotation angles due to a lack of significance in the reaction times between them. In the same response condition there was no main effect of the condition either low, medium or high,  $F(2,30)=.05$ ,  $p > .05$ , or type being color or temperature,  $F(1,30)=2.87$ ,  $p > .05$  as well as no interaction between the condition and type,  $F(2,30)=1.23$ ,  $p > .05$ . This can be seen in the large error bars in Figure 4.

Again, in the mirror response condition there was no main effect of condition,  $F(2,30)=.58$ ,  $p > .05$  or type,  $F(1,30)=1.45$ ,  $p > .05$ , and no interaction between them,  $F(2,30)=.59$ ,  $p > .05$  with large error bars again arising from the data which can be seen in Figure 5. No statistically significant data was found in the separate rotations either which is why they were condensed. A statistical analysis was run on the slopes of the data but yielded non-significant results, with error bars even larger than that of the reaction times.

### Discussion

Based on these results no evidence was found to support the idea that color causes effects because of a perceived temperature change. There are some reasons which may have led to this outcome. First there was an unusual degree of subject variability. Mental rotation tasks generally have a low variability and in this study it was rather high. This may have been caused by the color or the temperature, but there is no way of knowing without further data collection. The amount of variability paired with a low number of subjects in each condition yielded insignificant results even though there was some

variation between conditions. Secondly, the time subjects were exposed to each condition in the study may not have been as long as it needed to be. Participants may have needed to be exposed to the color or temperature for longer than the 5-10 minutes, provided by taking the survey, before taking the mental rotation task. Giving each condition more time to take hold may create significant results in the direction which was expected. Third, the temperature may not have been as extreme as it needed to be. Due to room constraints, 65 degrees Fahrenheit was the coolest the room would get to so the corresponding difference from the neutral temperature was used leaving only a 5 degree difference between each condition. Finally, mental rotation may not have been the correct test of reaction time because of its lack of accuracy reports and a possible practice effect. Even though there is normally a low variation between subjects in a mental rotation task, this particular program did not give the accuracy of the task and due to a practice effect there may have been some confounding variables built into the test its self which may be accounted for using a different task.

For future studies more extreme temperatures need to be used, possibly a 80, 70, 60 degrees Fahrenheit would create more of the effect desired. This more extreme temperature would make sure that participants were actually feeling a difference between the temperatures when a 5 degree difference may not have been noticeable. Also, the participants may need to be exposed to the interior space for a longer period of time to ensure the effect of the condition. One possibility could be having participants take multiple types of tests which could then be compared to one another to see when a color or temperature effect actually caused a change. This could show how long a person really needs to be exposed to an environment for it to have an effect. A within subject design

may remove the variance but the test would not be able to acquire a practice effect so mental rotation could not be used. Which brings a final suggestion, that different testing methods may simply be the answer. Attention, perception, and sensory memory, short-term memory, implicit learning, encoding specificity, judgment, or problem solving are just a few of the ideas which could be tested for their alterations due to color and temperature. Mental rotation had not been tested for it changes due to temperature or color so testing other cognitive processes which have been shown to be effected could yield a significant finding and the believed relationship between the two variables. Even though no statistically significant data was collected by this study on color and temperature differences on mental rotation, further research needs to be done to affirm or deny the idea that color and temperature effects are the same.

Figure 1

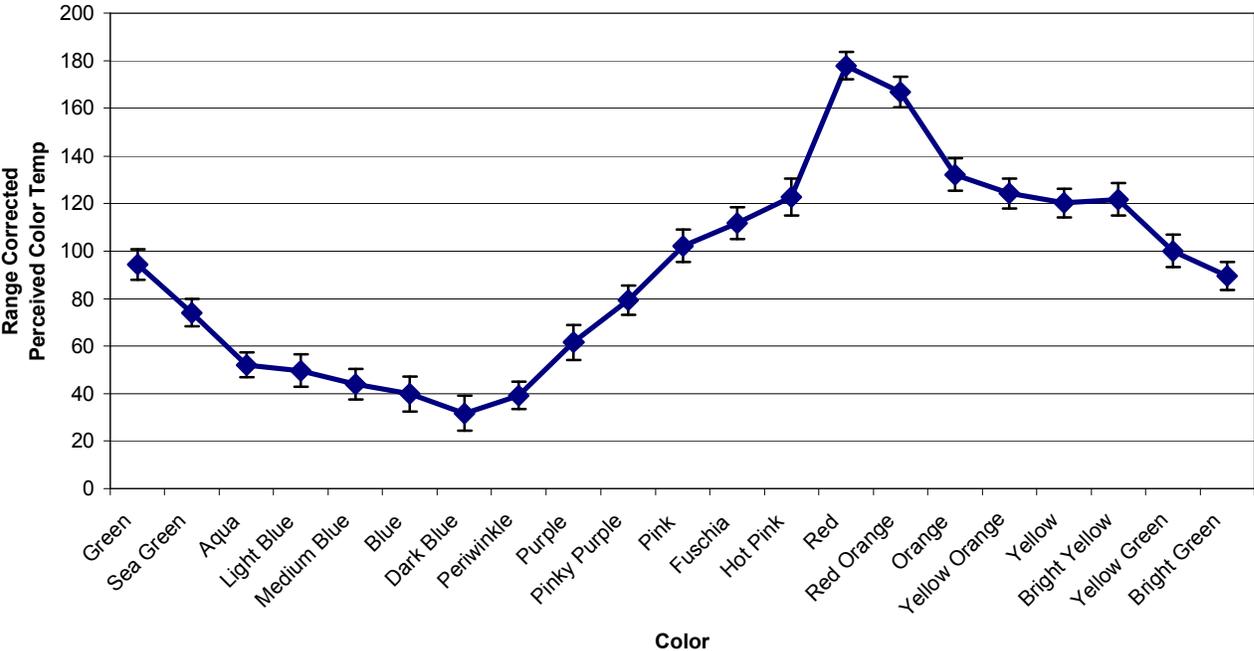


Figure 2



Figure 3

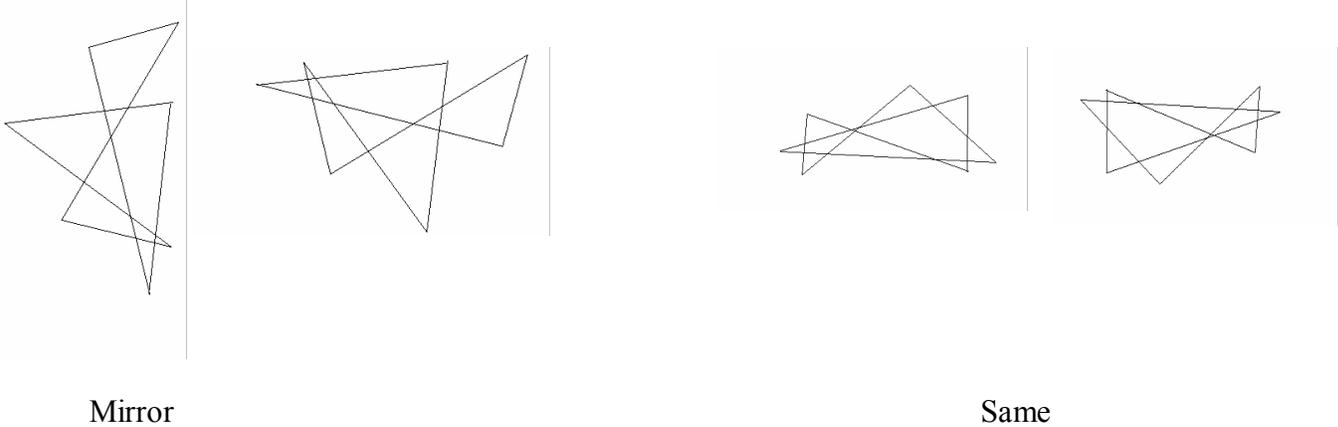


Figure 4

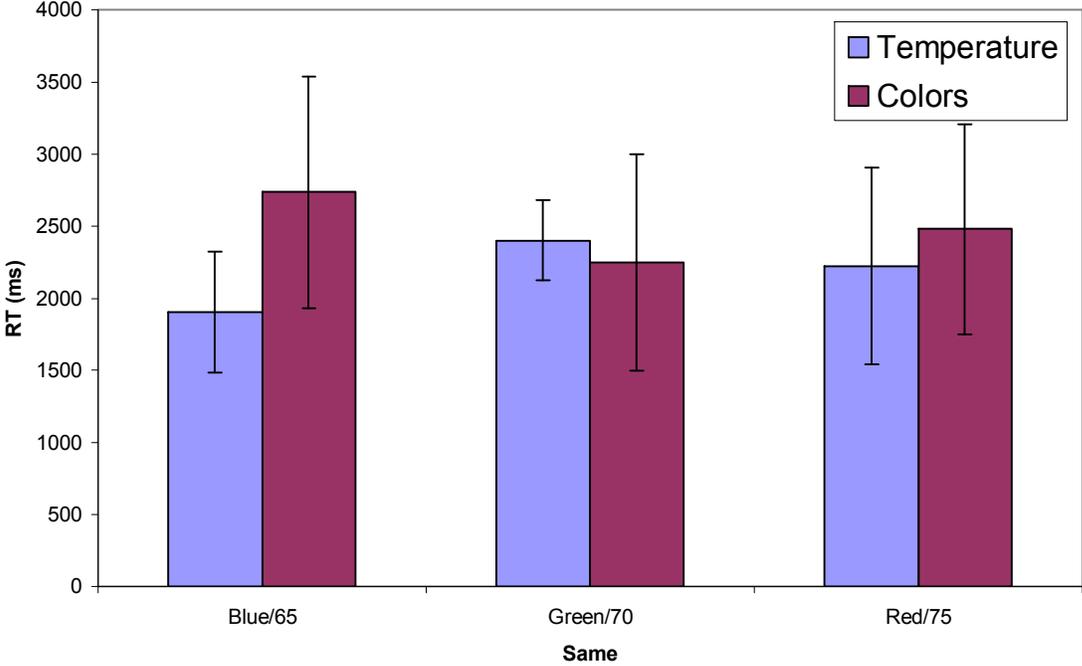
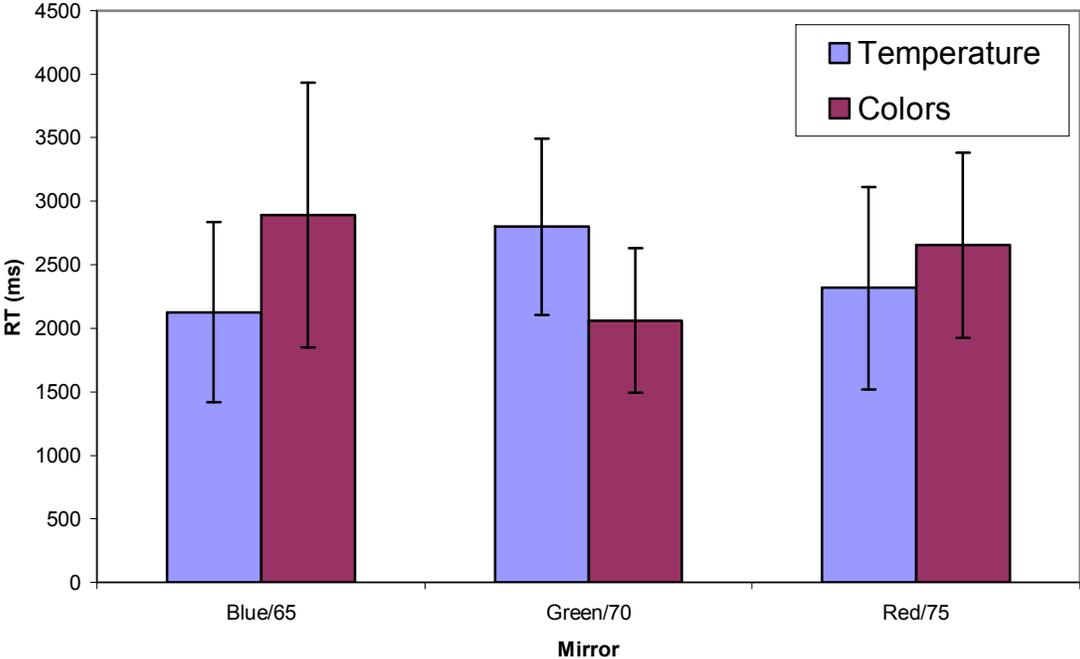


Figure 5



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