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The Effects of Affective Arousal on Color Perception and Memory

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by

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Dedication

There are many people who helped in the realization and implementation of this project to whom I owe my upmost gratitude.

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ABSTRACT

The link between affective arousal, color perception, and color memory was explored by inducing fear, sadness, or embarrassment in 158 participants who them completed a color perception and memory task. It was predicted that participants experiencing fear or embarrassment would more often correctly identify and remember red and green than a neutral condition whereas experiencing sadness would lead to less correct identification and memory for blue and yellow than neutral. There was only a marginally significant effect of fear on color memory for red. In the low arousal condition, there was an effect of fear on color memory for green and a marginally significant effect for red. Color perception and color memory scores were correlated for all colors except green. No direct effect of arousal level on color perception was found, however there may be an effect mediated by other factors. Red color memory may be modulated by fear.

Keywords: Color, perception, memory, arousal

The Effects of Affective Arousal on Color Perception and Memory

Color and emotional state are two concepts that are closely tied in human perception. In the past few decades studies have been conducted linking a particular emotional state to specific hues (Wexner, 1954). It is also thought that color stimuli can evoke emotional responses through these associations, such as in Kaya & Epps (2004) where participants were asked to come up with emotional vocabulary evoked by particular color swatches. The general conclusion from studies of this sort is that color can influence emotion. Most of this literature deals directly with the one-sided relationship of the effects of color on emotion. This leaves many other facets in this topic to be explored. Of particular interest is the opposite relationship; the influence of emotion on color perception.

Emotion, particularly sadness, is known to have many important psychological effects. A thorough review of the literature shows that depression is partially a sensory perception disorder as well (Fitzgerald, 2013)**.** Visual processing in depressed patients is impaired, thus affecting sensory perception of visual stimuli. This conclusion is corroborated by research in which patients with depression, regardless of medication being taken, show reduced contrast gain at the retinal level (Bubl et. al, 2010). This means that people are worse at detecting the differences in contrast between two scenes and this is occurring at the level of sensory input in the retina, not in the brain. In these cases, a persistent sad emotional state is actually affecting functioning of the visual system and cognitive processes. If this is the case, then is it not feasible that emotion could affect color perception as well? This was the question tackled by Thorstenson et. al (2015) in their recent publication. The authors looked at the effect of current emotional state on the accuracy of a color identification task. They found that induced sadness, through viewing of a

sad video clip, affected the perception of color. Participants were asked to identify the colors of swatches shown, either red, green, yellow, or blue. Specifically, participants had decreased capabilities when identifying yellow and blue color swatches at low saturation levels whereas this was not the case with the colors green or red. This effect was only found in the sadness induction condition, it was not present in the neutral or the amusement conditions.

The study conducted by Thorstenson and colleagues is the first study of its type to look at the impact of emotion on perception. This study has recently been retracted, however this retraction was simply due to the lack of a statistical analysis comparing the effects across the blue/yellow and red/green conditions. Although this omission does impact the results of Thorstenson's study, the principles which govern their results, specifically the theory that a psychological state can influence color perception, are unaltered. Thus, this study and it's methods will be vital for the development of this current research.

There are some very broad ranging applications for this type of research. Color is a strong factor in the advertisements we view every day. Color is also one of the main motivating factors in the arts, theater, dance, and many other artistic pursuits. If emotion does indeed affect color perception, this would provide more insight about great works of art and also would affect how advertisers create their work.

The Thorstenson et. al (2015) study relies on the most prominent theory of color vision: opponent-processing color theory (Hurvich & Jameson, 1957). This theory describes color vision as three opposing axises, green/red, yellow/blue, and white/black. Each axis uses processes of excitatory and inhibitory neural signals which are activated when light reaches the cones on the back of the eye. Based on this theory, we cannot perceive a "redish-green" or a "blueish-yellow"

as these processes cancel each other out. These colors paired by axises react together; when the perception of one is affected, as we see in the results of Thorstenson et. al (2015), so is the perception of the other. This can also be seen in simple tests of afterimages, a byproduct of the opponent process theory (Yantis, 2014). Afterimages are produced when looking at highly colored stimuli for several seconds without blinking. When that image disappears, the cones in the retina have become tired and they are tricked into showing the color at the other end of the axis until they can balance again. Based on the opponent process theory of color vision, in the current study we expect that the perception of red and green can be altered, as opposed to the results of Thorstenson et. al, which focused on the blue/yellow axis. Specifically, the red/green axis has ties with psychological states of affective arousal, or arousal induced by emotional state, this relationship becoming a focus of the current study.

It is important to consider an evolutionary perspective when dealing with the red/green axis. The development of color vision may have effects on the situations in which perception for certain colors was heightened or lessened. Traditionally, color vision was thought to have developed in order to further processes of hunting and gathering for food. It was important for our ancestors to be able to distinguish between ripe fruit, rotten fruit, and possibly poisonous food; “letting us find red berries among green leaves…” (Yantis, 2014, p. 153). This first theory of color vision shows how important these color axises are in more passive situations.

There is also another prominent theory of the evolution of color vision. This theory postulates that color vision developed in primates to differentiate between skin reflectance to detect blood flow. As Changizi et. al (2006) put it;

> The primate face and rump undergo colour modulations (such as blushing or blanching on the human face, or socio-sexual signalling on the chimpanzee rump), some which may be selected for signalling and some which may be an inevitable consequence of underlying physiological modulations.This second theory of color vision relies on the ability to distinguish the color red in skin tone. It has also been found that "skin redness enhanced the perceived health of faces" (Stephen et. al, 2009).

Situations in which it is important to perceive facial flushing are typically situations that involve general arousal. Arousal, in its many states, involves the activation of the sympathetic nervous system which governs over unconscious actions. The sympathetic nervous system is also tied to the color red; this part of the nervous system is actually known to specifically mediate facial flushing which we perceive to be red in color (Drummond & Lance, 1987). Such types of arousal include embarrassment (blushing), fear (flush from danger), sexual excitement, and some other strong emotional states. These types of arousal associated with specific emotional states fall under the umbrella of affective arousal. The current study thus hypothesizes that affective arousal shall have an effect on color perception. Specifically, it is hypothesized that affective arousal will facilitate greater perception of red and green. As previously stated, red is an important color to perceive when aroused with green being its axis partner in the opponent process theory. It is also expected that the results of Thorstenson et. al (2015) will be replicated: sadness should decrease the accurate perception of blue and yellow as sadness is not tied to a state of affective arousal that is associated with facial flushing.

If affective arousal state does indeed have an effect on color perception, there may also be an effect of arousal state on color memory. Arousal and memory are two topics with a

complicated relationship. Arousal is known to narrow one's attention, selecting for particularly stimulating details. Arousal also facilitates more efficient processing of stimuli, therefore making stimuli easier to attend to (Sharot & Phelps, 2004). This added attention to stimuli details and the efficiency of these encoding processes leads to better memory for stimuli when under the influence of any state of general arousal. Emotional state can also become intertwined with memory processes. In particular sadness is known to have influences on memory task performance, much more so than other cognitive tasks (Chepenik et. al, 2007). Emotional state and arousal state both impact memory at the level of encoding in these cases. It thus follows that the induction of these states in an experimental setting will have an impact on memory for stimuli. The intersecting paths of color, memory, and arousal play a role in the second hypothesis of this study. If arousal affects the perception of color, memory for color should be affected as well. Since it is predicted that arousal is increasing perceptive abilities for red and green, memory for these colors should be significantly greater when compared to a neutral state. Additionally, memory for yellow and blue colors should be decreased in the sadness condition since perceptual abilities for these colors are decreased.

Based on the above literature, the current study forms two main hypotheses. Firstly, if affective arousal does have an effect on color perception, then it is expected that there will be an increase in the correct identification of red and green color stimuli when embarrassment or fear is induced, but a decrease in correct identification of blue and yellow when sadness is induced. These increases and decreases will be ascertained according to a neutral baseline condition. The effect of the blue/yellow results across condition will also be compared to the effects of the red/green results to ensure that the axises have statistically significant difference (accounting for the

analysis which was the cause of the Thorstenson et. al (2015) retraction). Secondly, if arousal does have effects on color memory, than participants will have increased memory for red and green when embarrassment and fear are induced and decreased memory for yellow and blue when sadness is induced. The data from these conditions will also be compared to the results of the neutral condition to detect differences during analysis.

Method

Pilot Testing

A pilot testing procedure differed from the actual procedure so as to determine the exact stimuli used. Pilot tests were preformed to determine that the geometric shapes were not inherently associated with any of the four colors as well as determine the effectiveness of the arousal prompts. After completing an informed consent document, Participants were first presented with a sheet that lists the shapes in a column to the left and asked to identify which color best corresponds to the shape at hand (See Appendix D). Next, participants flipped the page to a second sheet which had an arousal-induction prompt on it, either fear, embarrassment, or sadness (See Appendix B). After reading the prompt, participants were asked to rate their mood and arousal levels on several scales, a modified version of the PANAS-X (Positive and Negative Arousal Schedule-Expanded Form, Watson & Clark, 1994) and the Perceived Arousal Scale (Anderson ,1995) (See Appendix C). Participants were then debriefed (See Appendix G).

A second round of pilot testing was required to implement a new set of arousal prompts after the first set proved ineffective. This second round used the final arousal prompts that were then used in the experiment (See Appendix E). In this pilot testing session, prompts were delivered on paper by the experimenter. Participants were asked to read a series of five sentences

and after each respond by writing a single word describing how they felt when the event in the sentence had occurred to them in the past. Participants were then debriefed.

Specifications

This experiment was approved by the Institutional Review Board of Bard College (See Appendix I) and published as a survey through Qualtrics, an online survey hosting platform. The link for this survey was published as a HIT (Human Intelligence Task) on Amazon's Mechanical Turk for a $0.50 reward following appropriate completion.

Before the study participants viewed the informed consent document (See Appendix F). Then they proceeded to a question asking if they had even been diagnosed with color-blindness or any other visual impairment which may affect their color vision. If participants responded that they were color blind or otherwise visually impaired, they were automatically re-routed to the end of the study and thanked for their time. All other participants proceeded to the demographic questions. The demographic questions had participants supply their age, gender, level of education, and ethnicity. The experimental tasks then commenced with the Arousal Prompt section.

Arousal Prompt Presentation

Participants were presented with a series of single sentence prompts that asked them to recall a time when they had experienced the event described in the sentence (i.e. "I mistook a stranger for a friend" or "I lost a pet"). For each arousal condition (neutral, fear, embarrassment, and sadness) there were five sentences describing common events which were meant to invoke the target arousal state. For the neutral condition sentences about boring, everyday tasks were used. (See Appendix E for list of prompts and accompanying instructions). All five sentences

were presented on the same page. After each sentence was a blank space in which participants were asked to write a single emotion that they felt when the event in the sentence was taking place. These responses were scored for strength using a 0-3 scoring system. Words which were the exact target or synonyms scored a 3, words which were of the same valence and could be related to the target were scored with a 2, words which were just of the same valence were scored with a 1, and words which were not of the same valence or were unrelated were scored with a 0 (for a list of example words by condition with scoring, see Table 1). Related words consisted of other emotional states that had overlapping aspects with the target emotion, such as "heart-broken" and "sadness". "Sadness" is one aspect of "heart-brokenness" which contains other aspects such as "loss" and "hurt". "Heart-broken" thus received a score of a 2.

Memory Object Presentation

In the next phase, participants viewed a series of 12 geometric shapes presented in red, yellow, blue, or green at 20% saturation with a black outline on a white background. (See Appendix A). Low saturation levels were used throughout the experiment to prevent ceiling effects of perception or memory. Before this task, participants were told that they were to try and remember the shapes they see and what colors they are presented in. All of the shapes were presented on a single page with no time limit. All of the shapes were distinct and three shapes were presented in each of the four colors. The order of the presented shapes was randomized, but color of the shapes was consistent between participants. Participants could spend as much or as little time as they liked memorizing the shapes. After participants felt they were ready to move on, they clicked the next button to advance to the color identification task.

Color Identification

This part of the procedure was adapted from Thorstenson et. al (2015). Participants were asked to determine the color of 24 color swatches at varying low saturation levels. Colors were be presented on a white background. The colors presented were either red, yellow, green, and blue and the saturation levels were 5%, 7%, 10%, 12%, 15%, or 20%. These stimuli were created using Adobe Photoshop just as they were created in Thorstenson et. al (2015) using their specified hue and brightness values (For color swatch stimuli, see Appendix A). Each color was shown in each saturation level once for identification. When the color swatches were presented, participants would identify their color by pressing a corresponding radio button with the color name next to it. The radio buttons were always presented in a left-to-right fashion in the order blue, red, green, yellow. Participants only viewed one swatch per page and could not proceed to the next page without making a selection. After viewing all 24 swatches, participants were directed to the memory task.

Memory Task

The final task was a memory exam for the geometric shapes presented in the memory object presentation phase. Participants were shown the same shapes from the original task and they were asked to identify the color which the shape was presented in originally. Each shape had a black outline and a white fill. Shapes were presented on an individual page with a white background. Color identification was in the same format as in the color perception task; each of four colors were presented horizontally next to a corresponding radio button. Participants had to select a button before they could move on the the next object and they could not go back to change their answers. Once all 12 objects had been given a selection, participants were directed to the happiness stimuli and the debriefing section.

Happiness Stimuli and Debriefing

After participants had completed all of the above tasks, they were shown the set of Happiness Stimuli (Appendix H). This was to ensure that all arousal induction conditions are impermanent, not lasting beyond the experimental period. The viewing of the Happiness Stimuli also reduces the risks to participant's mental health. On this same page, participants were asked to provide their Mechanical Turk ID number so that their results could be matched with their ID to assure payment. Finally, participants were debriefed and thanked (See Appendix G).

Results

Rejection Criteria

In total, 262 participants began taking the survey. Mechanical Turk provides requesters (in this case the experimenter) the choice of approving and rejecting work based on adequate completion of the task. Participants were automatically rejected if they did not complete the survey fully and if they did not provide their Amazon Mechanical Turk ID. Data from these participants were not coded. Participants were offered to contact the experimenter if they chose to discontinue the study for reasons of discomfort or if there was another reason they could not complete the survey so that they could receive credit. No participants contacted the experimenter about discontinuing the experiment. Participants were also rejected if they did not correctly complete the Arousal Prompt section of the study. They were rejected if they did not provide code-able answers to at least 3 of the 5 prompts (See Table 1). Often, participants would provide answers that were longer than one word (these were acceptable if they contained statements regarding target arousal status, i.e. "I was sad"), yes/no answers, color name answers, or true/ false answers. As the instructions provided for this task were clear to pilot participants, who had

none of these discrepancies, this was determined to be a reasonable cutoff. Participants were also rejected if they did not provide the correct study code (this code ensures that participants are in fact completing the study themselves and not using a computer program, similar to a captcha code). After these criteria were met, data from 158 participants were collected and analyzed (female, male). The SPSSStatistics package from IBM was used for all data collection and analysis.

Pilot Testing

The first section of pilot testing was conducted across three sections of 200 and 300 level Psychology classes at Bard College. 61 student voluntarily participated in the testing. Of the shapes presented, 12 were selected for the memory object task. These shapes were selected due to their low levels of association with any color (the bottom 12 shapes had a maximum association of 37% of participants with any particular color). In this first round of testing, the arousal prompts did not function as intended and there were no significant effects of any of the prompts on arousal levels or mood states. There were also no neutral prompts which raised concerns about consistence between conditions. This led to a second round of pilot testing with changed arousal prompts.

The second round of pilot testing had 10 voluntary participants recruited from the general campus of Bard College. All participants fully completed the arousal prompt task and they all scored above a 2 when their arousal prompt answers were averaged . Based on these scores, it was determined that these arousal prompts were effective at arousal induction and thus they were used in the experiment.

Demographic Information

There were 158 total participants after the rejection criteria were applied. Participants were randomly sorted into arousal categories with 33 participants in the neutral condition, 44 participants in the fear condition, 44 participants in the embarrassment condition, and 37 in the sadness condition. 73 participants identified as male, 84 identified as female and 1 person identified as non-binary. Most participants were White (72.2%), Asian (15.8%), Hispanic/Latino (5.1%) or Other (5.7%). As far as age is concerned, 65.2% of participants were between the ages of 25 and 44. 64.6% of participants hold the minimum of a four-year degree.

Color Perception

In the color perception task, responses were coded either as "incorrect" or "correct" color identifications. For each color category (blue, red, green, yellow) a mean score was calculated for every participant. These means were then grouped by arousal category and compared using a t-test for independent means (See Figure 1). There were no significant differences between fear, embarrassment, or sadness and the neutral condition for any color category, $t(75) < 1.32$, $p>0.05$. for all conditions. There was no effect of arousal condition on color perception when compared with the neutral condition.

These analyses were repeated with the least saturated color patches as well to see if there was any effect specifically at very low saturation levels (See Figure 2). There was no significant effect of arousal type at these saturation levels for any color category either, $t(75) < 0.95$, $p>0.05$ for all conditions.

This was repeated using the most saturated patches also. Again, there were no significant mean differences when fear, embarrassment, and sadness conditions were compared to the neutral condition regardless of color category, $t(75) < -.594$, $p > 0.05$. However, in the

embarrassment condition, participants scored perfectly on the red and green color swatches. Also in the fear condition participants achieved perfect scores for the green condition. In the neutral condition, participants had perfect scores in the blue, green, and red color categories.

In the Thorstenson et. al (2015) results, scores for color perception were grouped by blue with yellow and red with green. This analysis was conducted in this study as well to look for the patterns they found (See Figure 3). Neither the blue/yellow group nor the red/green group yielded any significant difference between arousal conditions and the neutral condition, $t(75) < 1.34$, $p > 0.05$.

Color Memory

Responses for color memory were coded in the same way as the color perception responses, they were either "incorrect" or "correct". Then scores were averaged for each participant and these means were compared by arousal category (See Figure 4). There was a marginally significant effect of fear on memory for the color red when compared to the neutral condition, $t(75)=1.834$, $p=0.071$; for Fear, $M=0.545$, $SD=0.353$; for Neutral, $M=0.494$, $SD=0.309$. If participants experienced the fear condition, they were more likely to correctly remember and identify red shapes than participants in the neutral condition. All other results were non-significant across arousal types and colors, $t(75)< 1.106$, $p>0.05$ for all conditions except red shapes and fear.

Arousal Level

Arousal levels varied greatly among participants. To see if there was any effect of level of arousal on color perception or memory, the arousal conditions were split into high and low arousal groups for subsequent analyses. The cut-off for these groups was determined by splitting

the groups around the median arousal level (*Med.*=1.80, See Figure 5). The low arousal group included those with a score of 1.80 as their arousal average. Since neutral condition was scored on a different scale (0 or 1 with one being a valenced emotion and zero being a non-emotion word) all of the neutral trials were included in both the low and high arousal tests.

In the high arousal group, there were no effects of arousal type when compared with the neutral condition for any of the color categories, $t(57) < 1.59$, $p > 0.05$. There also was no effect in the high arousal group of arousal type on color memory, $t(57) < 1.46$, $p > 0.05$ (See Figures 6 and 7).

In the low arousal group, there was a significant difference between the fear condition and neutral for green in the color perception task, $t(39.9) = 2.39$, $p < 0.05$. (See Figure 9). The fear condition had an effect on the perception of green more than in the neutral condition with participants in the fear condition performing significantly better at the task then participants in the neutral condition. There was also a marginally significant effect of fear on the red shape condition as well in the same direction, $t(41)=1.919$, $p=0.06$; for Fear, $M=0.633$, $SD=0.399$; for Neutral, $M=0.494$, $SD=0.309$.

Correlations Between Perception and Memory

Several correlational analyses were conducted between scores on the color perception task and the color memory task (See Table 2). When broken down by color we can see that there are significant Pearson's correlations between color perception and memory for blue, $r=0.17$, $p<0.05$, red, $r=0.22$, $p<0.01$, and yellow, $r=0.38$, $p<0.01$. Each of these are weak, positive correlation values indicating that correct answers on the color identification task predict correct answers on the color memory task for all colors except green, $r=0.03$, $p=0.76$.

Discussion

Conclusions

T-tests conducted comparing the sadness, fear, and embarrassment arousal conditions to the neutral condition revealed no significant effects of arousal on color perception. This was contrary to the original hypothesis, which predicted the different types of affective arousal would have different effects on color perception. It was also predicted that the current experiment would replicate the findings of Thorstenson et. al (2015) in which sadness decreased perception accuracy for blue and yellow. This result was neither replicated in the color perception analysis for all four colors nor in the grouped color perception analysis. Even when accounting for only the least saturated color patches, there was no significant effect of arousal on color perception. Thus, our main hypotheses were not supported by the data from the experiment.

The results for color memory accuracy revealed a marginally significant effect of the fear condition on identifying red shapes accurately. This analysis showed that participants in the fear condition were more likely to correctly remember the red shapes they saw marginally more than participants in the neutral condition. This result does align with the predicted effects of fear on color perception, however there were no other significant difference across arousal condition or color category, and as a marginally significant effect, it is not enough to refute the null hypothesis.

Additional analyses were performed to determine if arousal level may have any effect on the perception results. Participants were divided into groups of low and high arousal surrounding the median. In the high arousal group, there were no significant effects of arousal on color perception or color memory. In the low arousal group, there was the same marginally significant

effect of fear on memory for red shapes. There was also a significant effect of fear on perception for green swatches. Although there was no hypothesis concerning the different arousal levels, the results of the low arousal category line up with the general color memory and perception hypotheses for the fear condition.

The final analysis run was a correlation between color perception accuracy and color memory accuracy was conducted for each color condition. Blue, red, and yellow had positive significant correlations between perception and memory scores. Green had a non-significant positive correlation between perception and memory. The direction and significance of most of these correlations indicates that there is a relationship between perception and memory in this experiment.

Overall, the results of this experiment did not yield significant results supporting any of the hypotheses. However, it is important to note that the data from the perception task does reflect the directions predicted in the hypotheses. The t-test data from the perception accuracy shows red and green scores as slightly higher in the fear and embarrassment conditions then in the neutral condition. In the sadness condition we see lower scores in the blue and yellow categories than in the neutral condition. Although these scores were not significant, they do display a trend which can be explored further in subsequent experiments.

The data did not suggest a relationship between arousal states and color memory. There were no completely significant t-tests when comparing arousal states to the neutral condition for any of the color categories. The pattern of t-scores did not mirror the color perception scores, and they were not in the directions predicted.

The overall conclusions from this experiment also do not support the claims made by Thorstenson and colleagues in their 2015 paper. There was no significant effect of sadness on color perception. There are several reasons as to why we might see this result. In the current experiment, a different set of arousal stimuli were used. Thorstenson et. al (2015) used video stimuli while in this experiment, auto-biographical prompts were used. This choice was made to reduce possible confounds when videos were displayed as even if the stimuli were shown in black and white; they are well-known films and participants could remember the color of these scenes. Autobiographic prompts do not have this confound as they do not have associated color data. Since the experimental data suggest there was no pattern after the autobiographical arousal induction, it is possible that the videos do sway the results of the experiment or the arousal prompts functioned incorrectly.

It is important to note that three of the four color categories showed significant correlations between color perception and color memory. Red, blue, and yellow perception scores were correlated with their respective memory scores. This indicated that there is a relationship between perception and memory for color. This relationship might be mediated by other factors since all of these would be considered low correlations. In the case of green, it seems that there was no significant correlation between perception and memory. One possible explanation for this is that green was often confused with yellow during the memory task. Participants would often inaccurately identify green shapes as yellow shapes, whereas they often correctly identified green color swatches in the color perception task. This mismatch of memory objects could be the reason there was no correlation for the green color category.

Possible Confounds

There were several factors that may have influenced the experimental results. One of these is the strength of the arousal prompts. In the pilot testing, it was determined that a first set of autobiographical prompts were not sufficiently modulating arousal levels. This may have been influenced by time of day as each of the pilot testing sessions took place in the morning around 8:30 am. These first prompts as relied on participants to tell about a subjective memory which they were told to recall. The second set of autobiographical arousal prompts were created to correct issues with arousal manipulation strength and also have a more objective induction process. When pilot tested, these prompts induced the target emotion at high levels in every case. The difference of format between pilot testing and the experimental testing (physical paper versus computer screen) may have attributed to the lower arousal levels during the experimental sessions. There is also a difference in experiencing the same level of arousal caused by an action versus simply trying to recall and remember the way you felt at that time. This difference in strength may also have impacted the testing as participants were only recalling their experiences, not actually feeling them.

There may have also been a confound concerning the maintenance of arousal level over time. Arousal level after induction is known to decrease over various amounts of time depending on the strength of the original arousal induction. It may have been the case that arousal decreased back to base rates over the course of the experiment. This could be a reason why there was no relationship found between arousal prompt and color memory. If participants were no longer aroused when they had to recall the colors of the memory objects, there would be no predicted difference between the neutral condition and the other arousal conditions.

Another factor that should be addressed is the difficulty of the yellow stimuli. Overall, performance in the yellow category was very poor as yellow color swatches were often misidentified as green. This incorrect identification carried over into the color memory task as well, with green and yellow objects often being confused. As mentioned earlier, this may have led to the lack of a significant correlation between green perception and memory. The difficulty in identifying yellow may point to an issue with this set of color stimuli which may have affected the results of both this experiment and research by Thorstenson et. al (2015).

Although none of the color perception analyses revealed significant differences between the neutral condition and other arousal conditions, when looking at the t-scores we do see a visual pattern that adheres to the predictions made. It is possible that there is no direct relationship between arousal and color perception, but instead an indirect relationship which includes other variables. One of these possible variables is attention. In the current experiment, attention was difficult to control as participants took the survey independently online. The nature of the Mechanical Turk platform has workers taking surveys for monetary rewards so many participants are taking the survey as fast as they can so they can maximize their earnings over time. This may have led to a lack of attention for the arousal prompts or the color swatches which would greatly affect results.

In general, the use of an internet survey for data collection has some inherent problems. There is less control over the environmental conditions of each participant. In particular, there was no way to control how the stimuli were viewed as each participant is using their own computer. This factor is a trade-off for collecting larger amounts of data in a short amount of

time. Due to the quantity of the data needed for this experiment, this method was probably most appropriate, if not the most ideal method of data collection.

Future Directions

Overall, there are several factors that may have contributed to the lack of significant results in the current study. If this experiment were to be adapted for future use, these confounding factors should be addressed to better explore the connections between arousal, color perception, and memory. Firstly, the arousal prompts should be modified to better induce the arousal conditions. This could be accomplished through either changing the type of arousal prompt (to a video without color or a photograph) or changing the environment of the arousal induction (having the experiment conducted in person). This would require more extensive pilot testing to determine the best method of arousal induction for the experiment.

It would also be beneficial to revisit the color perception stimuli as well. Although these stimuli seemed to function in previous research, they were problematic in the current experiment, especially the yellow stimuli. Perhaps these can be replaced with less saturated color swatches or yellow swatches with different hue and brightness values. These stimuli should also be extensively pilot tested to assure that they are identifiable and variable.

There should also be a control of attention in any additional experimentation. Attention could be self-reported or controlled through testing in a lab environment. If analyses then controlled for attention we could see a possible interaction between this and arousal type on color perception and memory.

This experiment could also be incorporated into future explorations on related topics. One of these possible future directions is to look at other factors which may effect color

perception or color memory. In particular, there may be effects of certain valences of emotion (positive or negative) or certain, more specific, levels of arousal (very high, very low) on color perception and thus memory. Results from these experiments could influence a variety of fields including creative practices, productive design in workplaces, or effective advertisement. It could also show the cyclical nature of color perception and internal states where each has an effect on the other.

The results from this experiment show that if there is a relationship between affective arousal and color perception/memory, it is most likely modulated by other factors. Hopefully, this interesting intersection between the artistic and the emotional will be further explored as it could reveal results that have far-reaching impacts. Although this experiment did not yield the predicted results, it does pave the way for future research in the areas of color perception and memory.

Tables and Figures

Table 1

Example Arousal Prompt Answers Sorted by Score

Score	Neutral	Fear	Embarrassment	Sadness
0 **unvalenced or incorrect valence**	natural protected stylish child-like active	curious unconscious lucky numb annoyed	unique proud untidy calm dirty	stoic ennui
1 **correct valence**	bad good happy comfortable nice relaxed satisfied healthy	uncomfortable apprehensive terrible suspicious sad	sad surprised wrong distraught nervous agitated	regret confused disappointed alone incomplete self-hatred frustrated
2 **correct valence and related concept**	N/A	shocked shaky dread alarmed creepy nervous anxious worried	flustered uncomfortable horrified awkward guilt	heart-broken shock hurt down awful pain sorry
3 **target or synonym**	N/A	afraid panic scared startled terrified frightened	embarrassed shame mortified humiliated	sad upset unhappy sorrow grief depressed destroyed devastated

Table 2

Correlations between Perception Accuracy and Memory Accuracy by Color

		Perception Accuracy			
		blue	red	green	yellow
Memory Accuracy	blue	0.174*	-	-	-
	red	-	0.215**	-	-
	green	-	-	0.025	-
	yellow	-	-	-	0.377**

* indicates Correlation significant at $p<0.05$

** indicates Correlation significant at $p<0.01$

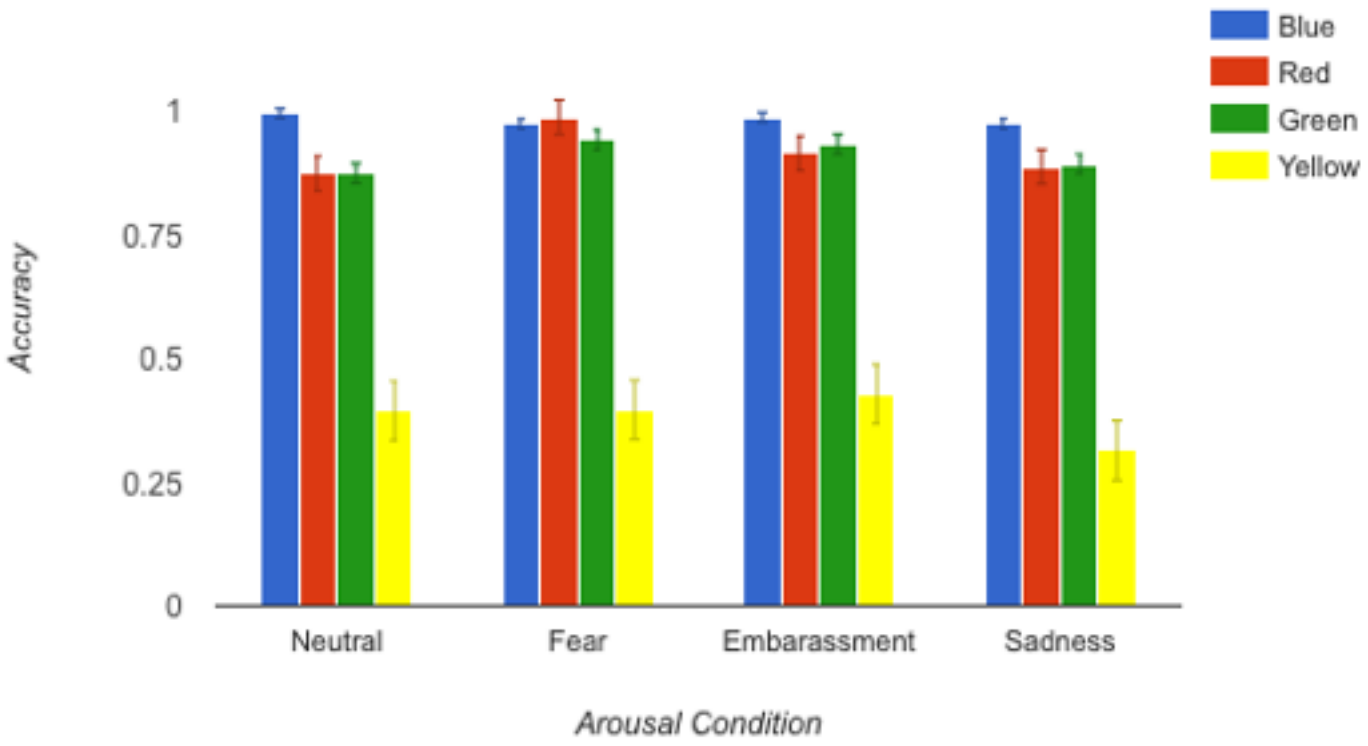

Figure 1. The effect of arousal condition on color perception accuracy.

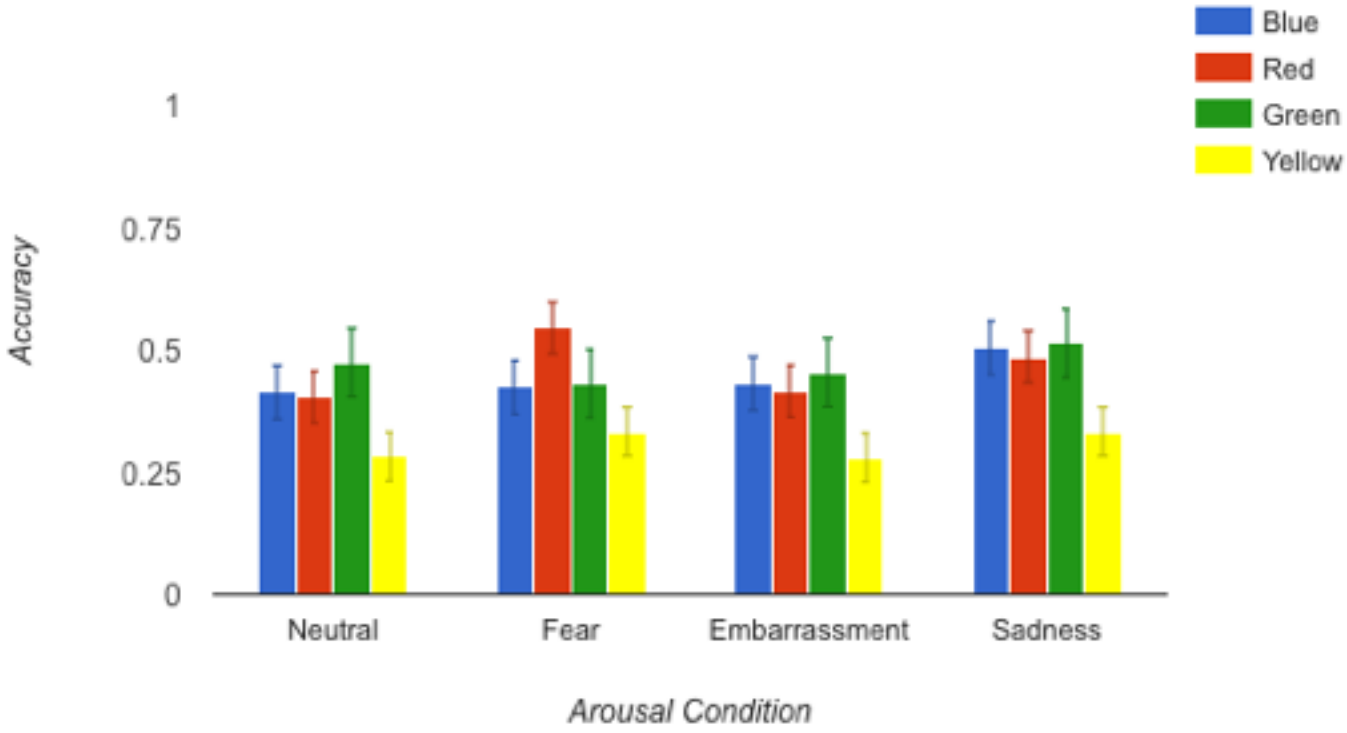

Figure 2. The effect of arousal condition on color memory accuracy. Red accuracy in the Fear condition was marginally significant when compared with neutral, $t(75)=1.834$, $p=0.071$; for Fear, $M=0.545$, $SD=0.353$; for Neutral, $M=0.494$, $SD=0.309$.

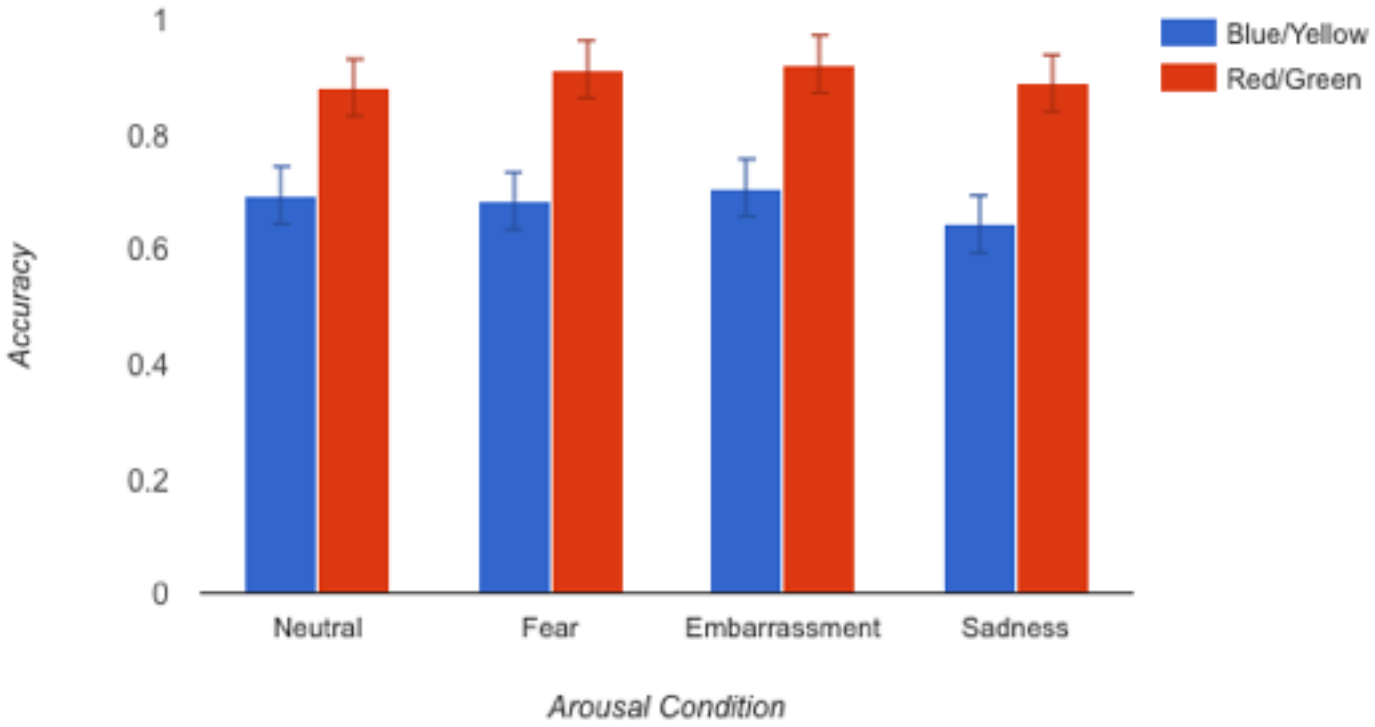

Figure 3. The effect of arousal condition on color perception when grouped by opponent process theory axis.

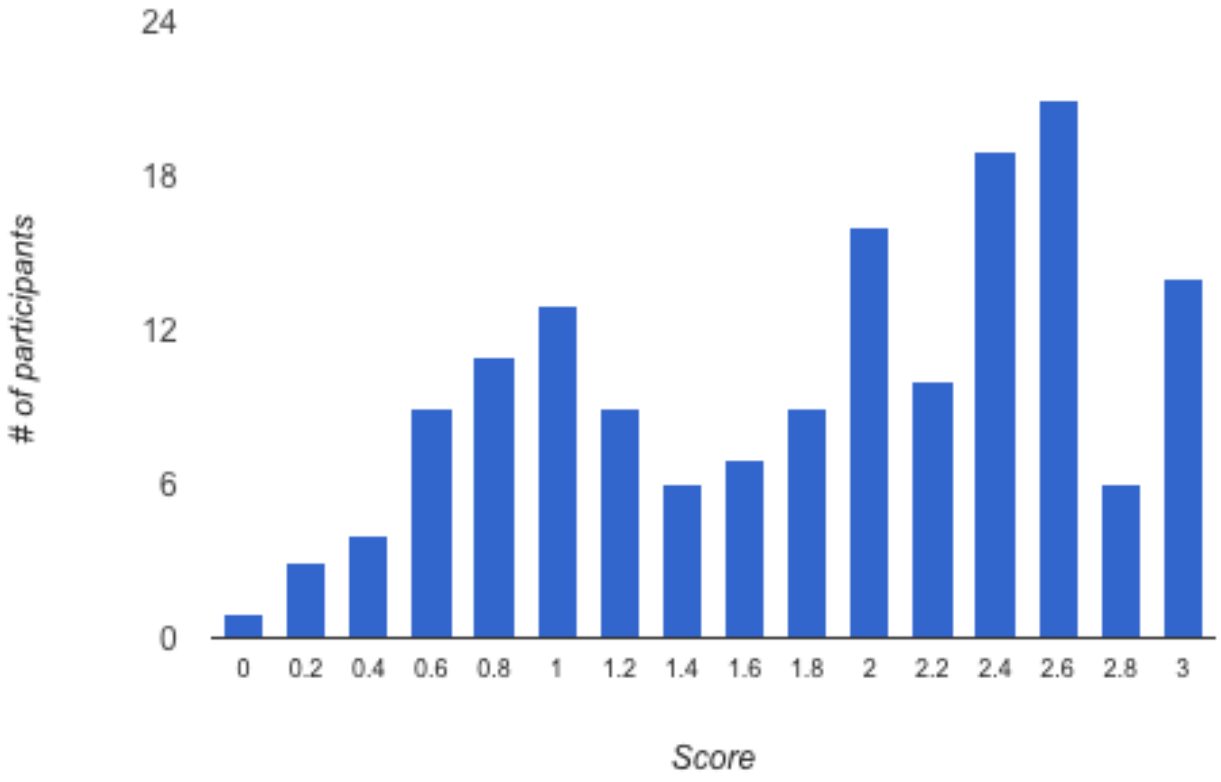

Figure 4. The distribution of average arousal scores for all arousal conditions.

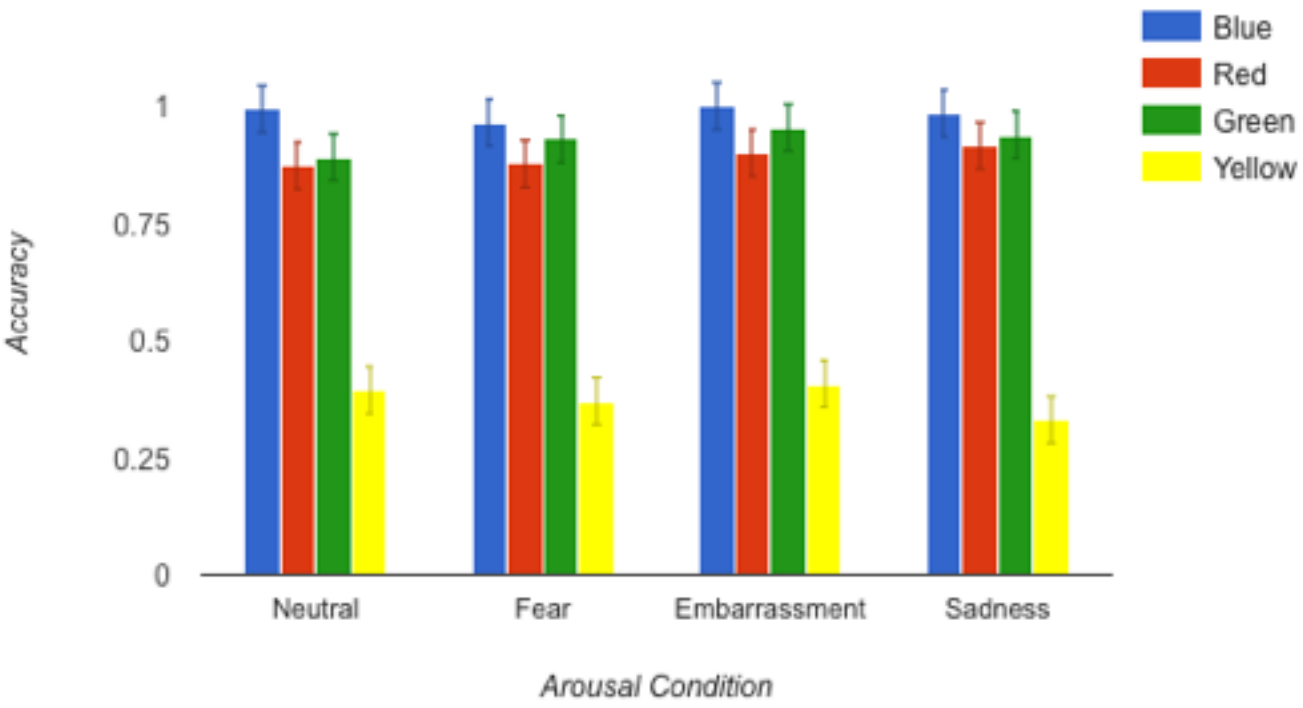

Figure 5. The effect of arousal condition on color perception with only participants with high arousal scores.

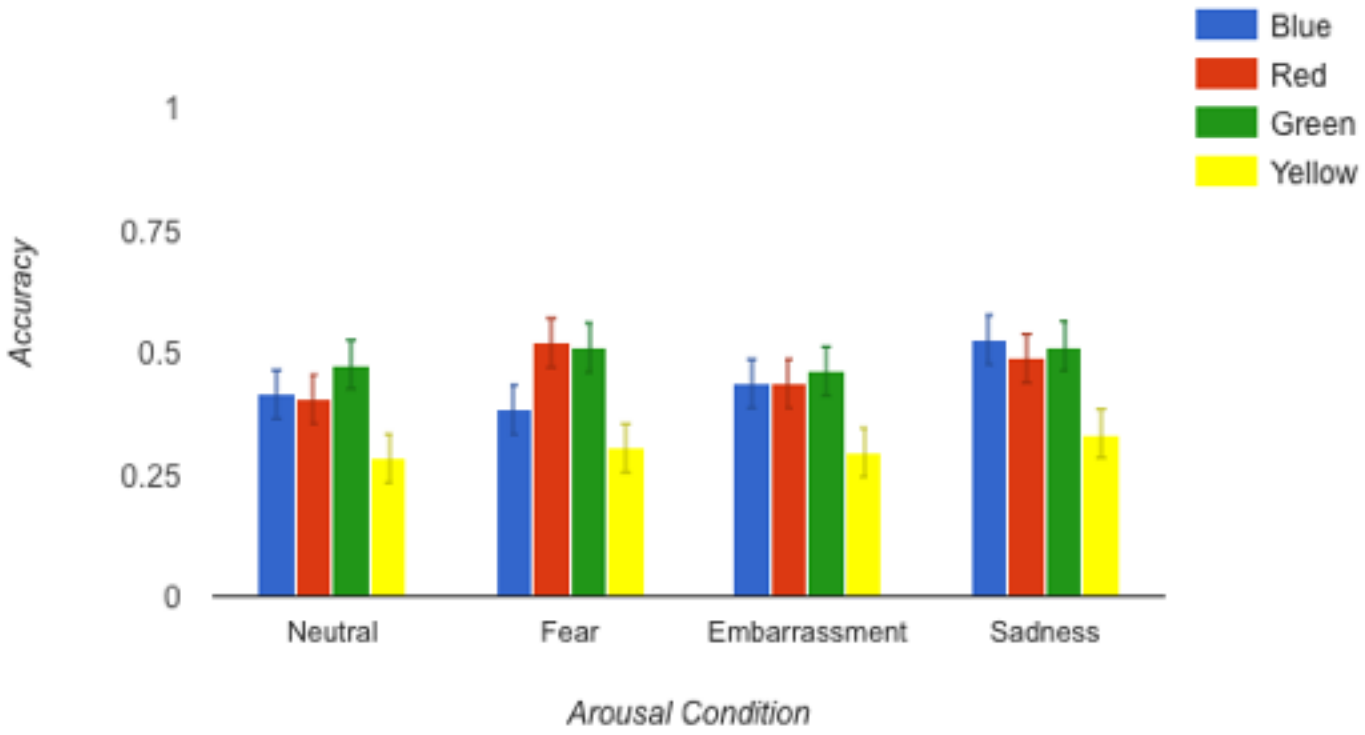

Figure 6. The effect of arousal condition on color memory with only participants with high arousal scores.

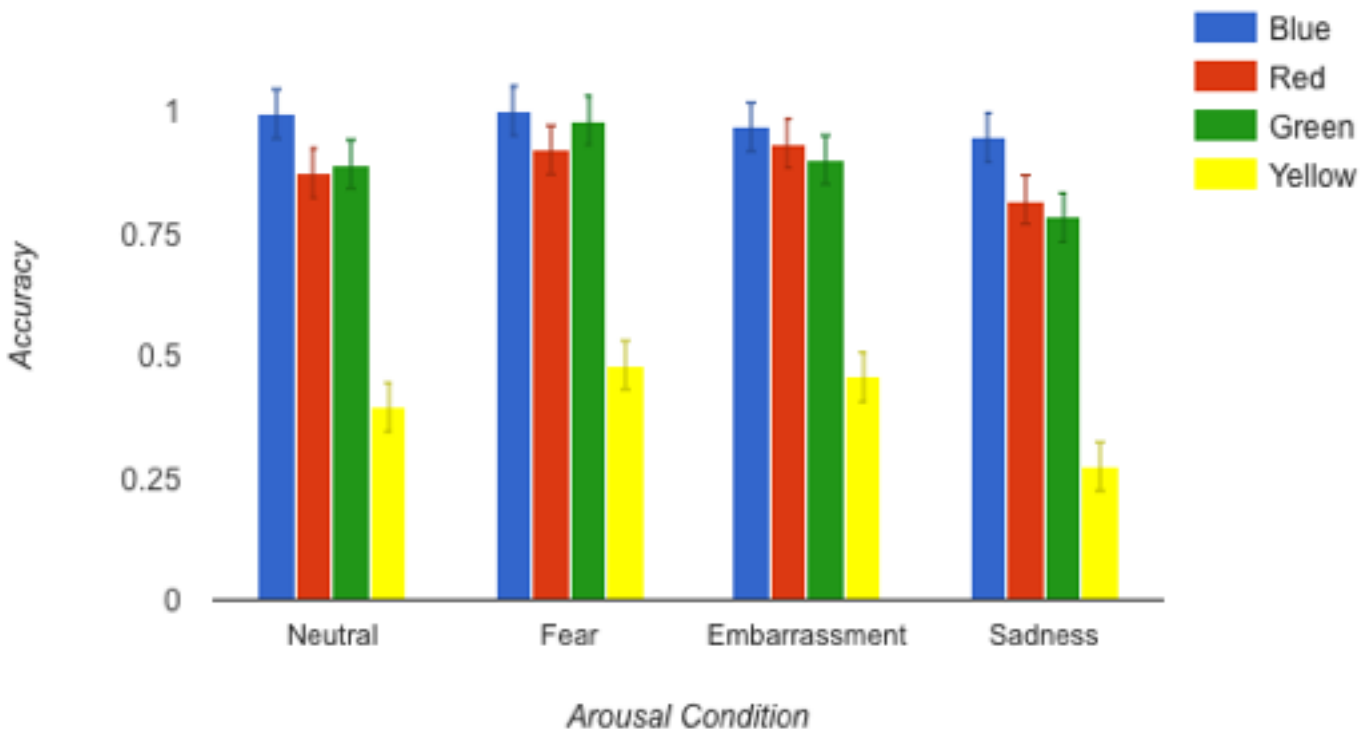

Figure 7. The effect of arousal condition on color perception with only participants with low arousal scores.

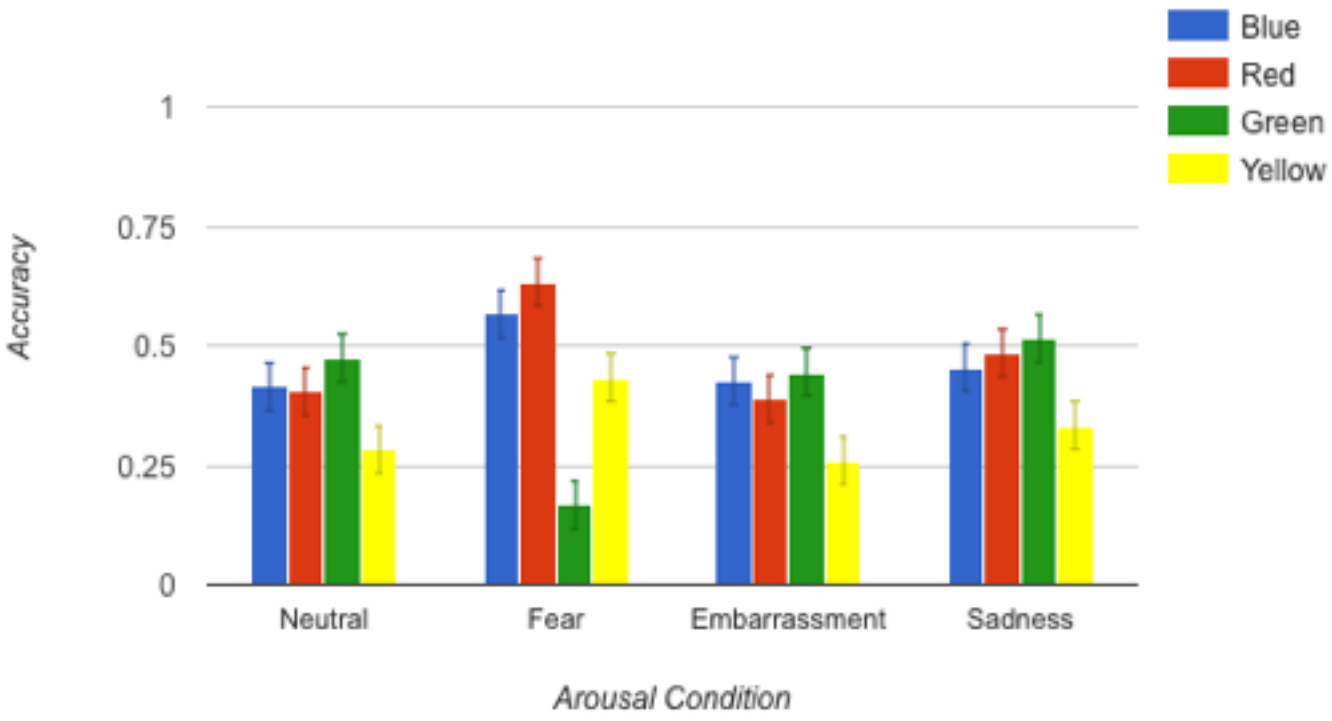

Figure 8. The effect of arousal condition on color memory with only participants with low arousal scores.

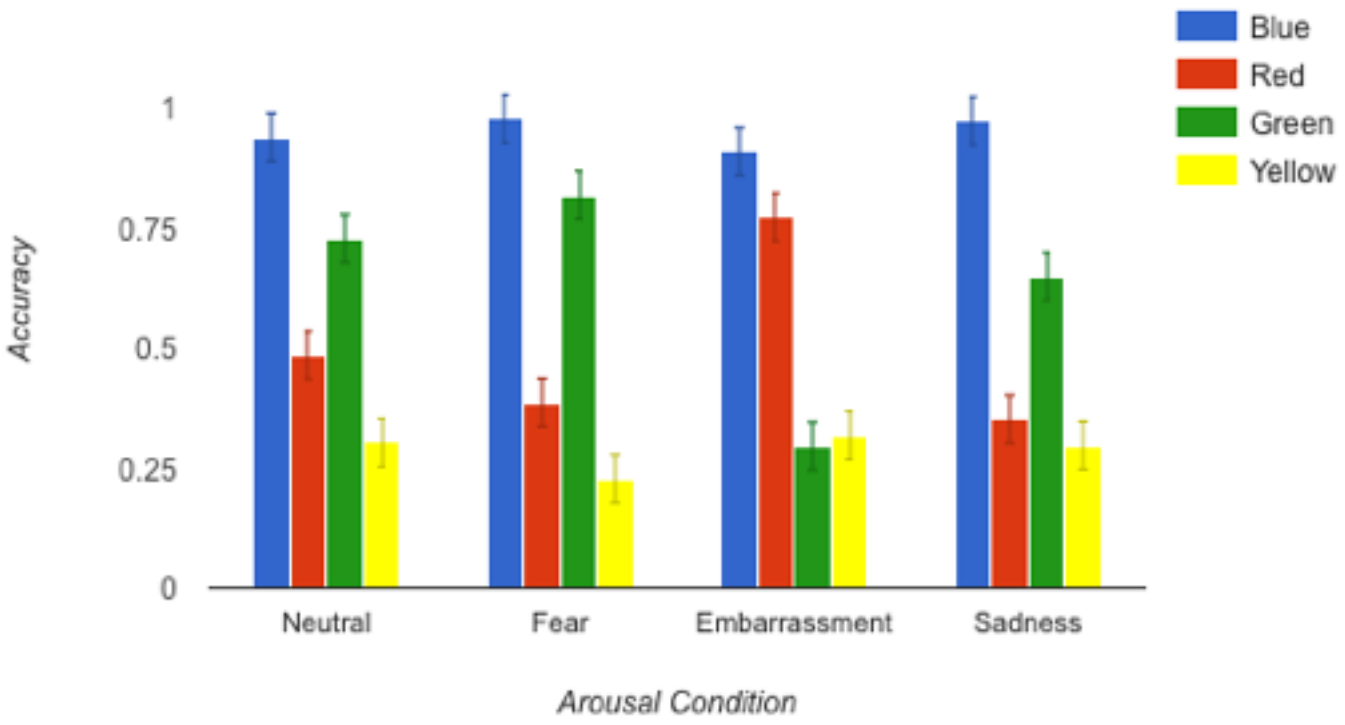

Figure 9. The effect of arousal condition on color perception with only the least saturated color patch scores.

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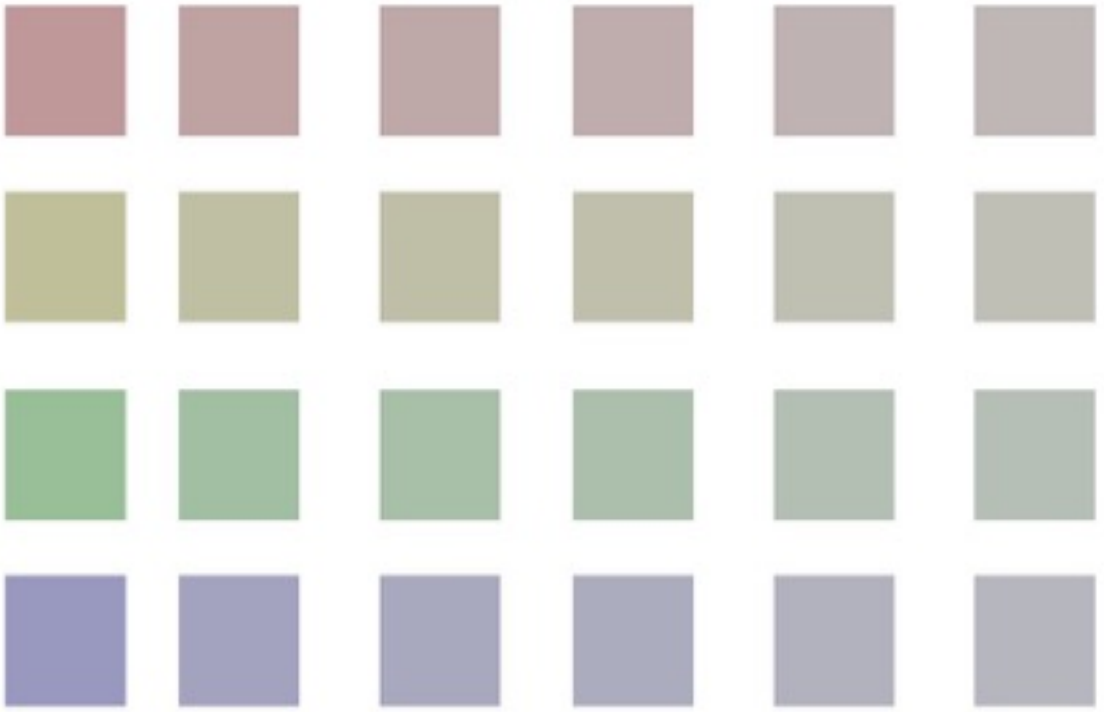
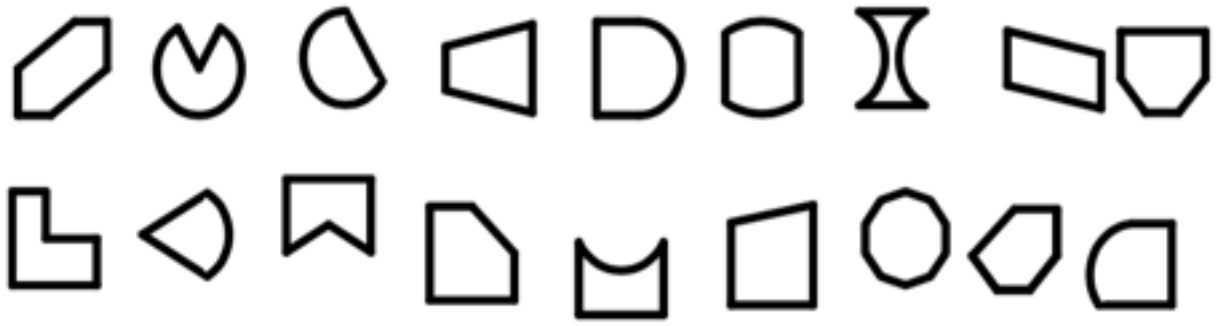
Appendix A

Color Perception Swatches and Memory Objects Stimuli





Appendix B

Arousal Prompts Pilot 1

Instructions:
Please take a moment and read the following directions to yourself. After reading the instructions, you will be asked to write a list summarizing the experience you were reliving, these answers will remain anonymous, they are just included to check that you are reading all of the instructions. If at any point in time you feel uncomfortable during this task and wish to discontinue the experiment, simply inform the experimenter that you would like to leave.

Fear

Try to visualize the last time in your life you felt endangered or that your security was threatened. Remember where this event took place. What time of year did this event take place? What time of day was it when the event was happening? Think about the imminent danger that was approaching you. Revisit the exact way you felt at this time. Recall if your fear was for yourself or for others close to you. Remember every detail you can of the event. In the space below, write as many details of the event as you can, either in response to the above questions, or other memories you may have. Specifically, try to recall the exact feeling you had during this event.

Embarrassment

Try to visualize the last time in your life you felt embarrassed or ashamed. Remember where this event took place. What time of year did this event take place? What time of day was it when the event was happening? Think about the cause of your embarrassment. Revisit the exact way you felt at this time. Recall if your shame was about something you said or did. Remember every detail you can of the event. In the space below, write as many details of the event as you can, either in response to the above questions, or other memories you may have. Specifically, try to recall the exact feeling you had during this event.

Sadness

Try to visualize the last time in your life you felt sad enough to cry. Remember where this event took place. What time of year did this event take place? What time of day was it when the event was happening? Think about the cause of your sadness. Revisit the exact way you felt at this time. Recall if your sadness was caused by another or yourself. Remember every detail you can of the event. In the space below, write as many details of the event as you can, either in response to the above questions, or other memories you may have. Specifically, try to recall the exact feeling you had during this event.

Appendix C

Pilot Shape Selection Task

Please select or write in the color that you think BEST corresponds to the shape in the left column. Choose the color that you most associate with the shape. Only select one color or write in a color option in the blank provided. If you are unsure or feel that no specific color corresponds the the shape, write “None” in the blank. When you have finished this sheet, please turn it in to the experimenter to receive the second part of the experiment.

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____

RED YELLOW GREEN BLUE OTHER_____


RED YELLOW GREEN BLUE OTHER_______________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RED YELLOW GREEN BLUE OTHER_______________


RED YELLOW GREEN BLUE OTHER_______________


RED YELLOW GREEN BLUE OTHER_______________


RED YELLOW GREEN BLUE OTHER_______________

Appendix D

Mood and Arousal Scales

Modified PANAS-X (Watson & Clark 1994)

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way during the past few weeks. Use the following scale to record your answers:

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

_____ cheerful	_____ disgusted	_____ attentive
_____ bashful	_____ sluggish	_____ daring
_____ surprised	_____ strong	_____ scornful
_____ relaxed	_____ irritable	_____ delighted
_____ inspired	_____ fearless	_____ disgusted
_____ sad	_____ calm	_____ afraid
_____ tired	_____ amazed	_____ shaky
_____ happy	_____ timid	_____ alone
_____ alert	_____ upset	_____ angry
_____ bold	_____ blue	_____ shy
_____ active	_____ guilty	_____ joyful
_____ nervous	_____ lonely	_____ sleepy
_____ excited	_____ hostile	_____ proud
_____ jittery	_____ lively	_____ ashamed
_____ at ease	_____ scared	_____ drowsy
_____ angry at self	_____ enthusiastic	_____ downhearted
_____ sheepish	_____ distressed	_____ blameworthy
_____ determined	_____ frightened	_____ astonished
_____ interested	_____ loathing	_____ confident
_____ energetic	_____ concentrating	_____ dissatisfied with self
_____ embarrassed		

Perceived Arousal Scale (Anderson 1995)

Different people react very differently to the same situations. Indicate to what extent you feel this way right now, that it, at the present moment. Use the following 5-point rating scale. Write the number corresponding to your rating on the blank line next to each word.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

_____ active	_____ alert	_____ aroused	_____ depressed
_____ drowsy	_____ dull	_____ energetic	_____ excited
_____ exhausted	_____ fatigued	_____ forceful	_____ inactive
_____ lively	_____ powerful	_____ quiet	_____ sharp
_____ sleepy	_____ slow	_____ sluggish	_____ tired
_____ vigorous	_____ weak	_____ weary	_____ worn-out

Appendix E

Final Arousal Prompts

Please read each of the following sentences carefully. After each one, pause and imagine a time when what happened in the sentence also happened in your life. Recall carefully how you felt when this event occurred. In the blank space below, please write the feelings you felt at this time, one for each sentence. These may be the same emotion, or different ones. If the event in the sentence has never occurred to you, move on to the next one and write N/A in the blank.

Embarrassment:

I was not dressed properly for the occasion.
I mistook a stranger for my friend.
I noticed that the zipper of my pants was open.
I soiled my underwear.
I farted in a public elevator full of people.

Fear:

I heard a loud noise in my house when no one else was home.
I was involved in an accident.
I almost fell from a very high place.
I had a nightmare that woke me up.
I thought someone was following me in a strange place.

Sadness:

I lost a family member who I was close to.
I misplaced my most prized possession.
I lost a close friend.
I ended an enjoyable relationship.
I lost a pet.

Neutral:

I wore a hat.
I sat on a chair.
I saw a bird.
I drank some water.
I picked up a ball.

Appendix F

Informed Consent

The pilot study you will be participating in today is part of a Senior Project in Psychology conducted by Nicole Lang and advised by Thomas Hutcheon. This study should take 10 minutes to complete. The current research focuses on the cross section of emotion and color perception. The purpose of this experiment is to gain more knowledge of human perception of various colors. In this study, you will participate in a survey about color association and shapes. Then you may read a prompt and be asked to write a detailed description of a memory you have. Finally, you will answer a short survey about your current emotional state and arousal state. After your participation you will view a series of happiness stimuli.

Your name and signature will only be present on this form. After participation, this form shall be stored in a sealed envelope and all other data shall only be identified with a participant code, serially generated. All of your identification information will be stored separately from your answers to ensure confidentiality.

This experiment does pose the risk of mild emotional discomfort as you may be asked to remember a sad, embarrassing, or fearful memory in detail. This recollection exercise will be brief and after the experimental procedure, you will view a series of happiness stimuli to reverse any mood changes. The benefits of your participation today are access to a preliminary color-blindness test as well as greater knowledge of how a psychological study is conducted. You will be compensated with candy after participation. If at any point in time you would like to discontinue the experiment, please let the researcher know. If you choose to discontinue the experiment, you will still receive candy.

The finished product of this research will be permanently and publicly available as a Senior Project at the Stevenson Library of Bard College.

If you have any questions or concerns, please feel free to contact Nicole Lang (nl9881@bard.edu) or Thomas Hutcheon (thutcheo@bard.edu). You may also contact the Institutional Review Board of Bard College through email (irb@bard.edu) or the chair of the IRB Pavlina R. Tcherneva (tchernev@bard.edu) if you have concerns about your rights as a research participant.

If you have concerns about your mental health after participation, please contact BRAVE (845-758-7777 and ask to speak to a BRAVE counselor or email Rebecca Stacy at stacy@bard.edu) or health services (845-758-7433).

I have read and understand the above information and voluntarily agree to participate in the research project described above. I accept the risk of harm described above as well as the benefits. I am also above 18 years of age.

Print Name_____

Signature_____

Date_____

The study you will be participating in today is part of a Senior Project in Psychology conducted by Nicole Lang and advised by Thomas Hutcheon. This study should take 15 minutes to complete. The purpose of this experiment is to gain more knowledge of human perception of various colors. In this study, you will be asked to view a series of shapes. Afterwards, you will be asked to recall a memory and type out the details you can remember. Then you will participate in a color identification task followed by a memory task. After your participation you will view a series of happiness stimuli.

All of the identification information the research team will have access to will be your Mechanical Turk ID number and your location. This information will be password protected and only available for access by the experimenter. The rest of your data will be identified will a serially generated participant code. All of your identification information will be stored separately from your answers to ensure confidentiality.

This experiment does pose the risk of mild emotional discomfort as you may be asked to remember a sad, embarrassing, or fearful memory in detail. This recollection exercise will be brief and after the experimental procedure, you will view a series of happiness stimuli to reverse any mood changes. There may also be the risk of mild eye-strain due to viewing the study on a computer screen. The benefit of your participation today is access to a preliminary color-blindness test. You will be compensated with fifty cents after participation. If at any point in time you would like to discontinue the experiment, you may do so by exiting the survey. You may still submit a HIT to receive payment, however you must contact the researcher through Amazon's Mechanical Turk system or via email to receive compensation otherwise your HIT will be rejected.

The finished product of this research will be permanently and publicly available as a Senior Project at the Stevenson Library of Bard College.

If you have any questions or concerns, please feel free to contact Nicole Lang (nl9881@bard.edu) or Thomas Hutcheon (thutcheo@bard.edu). You may also contact the Institutional Review Board of Bard College through email (irb@bard.edu) or the chair of the IRB Pavlina R. Tcherneva (tchernev@bard.edu) if you have concerns about your rights as a research participant.

If you have concerns about your mental health after participation, please contact *The Samaritans 24-hour Hotline* (1-212-673-3000).

By continuing with this survey, I affirm that I have read and understand the above information and voluntarily agree to participate in the research project described above. I accept the risks of harm described above as well as the benefits. I acknowledge that I am 18 years of age or above.

Appendix G

Debriefing Forms

Thank you for your participation in this pilot study. The purpose of this research is to gain more knowledge of how emotional states and arousal affect color perception. Recent research (Thorstenson et. al 2015) has found that induced sadness alters the perception of colors on the yellow and blue axis at low saturations.

You have participated in pilot test for an upcoming experiment. This study is focused on manipulating arousal to try and alter perception of colors on the red and green axis. The first pilot test you competed were to determine if certain shapes were associated with different colors. This data will be analyzed to determine a subset of shapes to be used in the experiment that are not explicitly associated with any particular color. The second section of testing was used to determine if arousal induction prompts (embarrassment, sadness, or fear) could induce the target emotion in participants. The induction prompt you read was followed by an arousal questionnaire as well as a emotional scale questionnaire to determine if these prompts are indeed viable. Your answers from these questionnaires will determine which prompts are used in the experiment. The detail descriptions written during the induction phase will be kept confidential as these were only to measure if participants are reading and thinking about the prompts given.

If you have any questions or concerns, please feel free to contact Nicole Lang (nl9881@bard.edu) or Thomas Hutcheon (thutcheo@bard.edu). You may also contact the Institutional Review Board of Bard College through email (irb@bard.edu) or the chair of the IRB Pavlina R. Tcherneva (tchernev@bard.edu) if you have concerns about your rights as a research participant.

If you have concerns about your mental health after participation, please contact BRAVE (845-758-7777 and ask to speak to a BRAVE counselor or email Rebecca Stacy at stacy@bard.edu) or health services (845-758-7433).

Thank you again for your participation!

Thank you for your participation in this study. The purpose of this research is to gain more knowledge of how emotional states and arousal affect color perception. Recent research (Thorstenson et. al 2015) has found that induced sadness alters the perception of colors on the yellow and blue axis at low saturations.

The experiment you have participated in is focused on manipulating arousal to try and alter perception of colors on the red and green axis. You were asked to recall a memory which you associate with embarrassment, fear, or sadness (unless you were placed in the control condition in which you had no arousal prompt). It was hypothesized that participants in the embarrassment and fear conditions would be significantly better at identifying red and green than those in the neutral condition and that participants in the sadness condition would be significantly worse at identifying yellow and blue colors. It was also hypothesized that participants in the embarrassment and fear conditions would have better memory for the red and green shapes presented while the sadness conditions would have worse memory for the yellow and blue shapes presented than those in the neutral condition.

If you have any questions or concerns, please feel free to contact Nicole Lang (nl9881@bard.edu) or Thomas Hutcheon (thutcheo@bard.edu). You may also contact the Institutional Review Board of Bard College through email (irb@bard.edu) or the chair of the IRB Pavlina R. Tcherneva (tchernev@bard.edu) if you have concerns about your rights as a research participant.

If you have concerns about your mental health after participation, please contact *The Samaritans 24-hour Hotline* (1-212-673-3000).

Thank you again for your participation!

Appendix H

Happiness Stimuli

Appendix I

IRB Approval Letter

Bard College Institutional Review Board

Date: December 10, 2015
To: Nicole Lang
Cc: Thomas Hutcheon, Megan Karcher
From: Pavlina R. Tcherneva, IRB Chair
Re: December 2015 Proposal

DECISION: APPROVED

Dear Nicole,

The Bard Institutional Review Board reviewed the revisions to your proposal. Your proposal is approved through December 10, 2016. Your case number is 2015DEC7-LAN.

Please notify the IRB if your methodology changes or unexpected events arise.

We wish you the best of luck with your research.

Pavlina R. Tcherneva
tchernev@bard.edu
IRB Chair

Appendix J

NIH “Protecting Human Research Participants” Certificate

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Nicole Lang** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 02/26/2014.

Certification Number: 1415796.