Influence of Emotion on Color Perception Processes

by

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Abstract

The effects of congruence, hue, and word type were measured through reaction times (RTs) in the context of an adapted Stroop task to determine whether emotion has a significant effect on color perception. Responses were faster to respond to color words than they were to emotion words. In trials for which emotion terms were congruently presented in their associated color, participants responded faster than they did for trials when emotion terms were presented incongruently in nonassociated colors. These findings suggest that associations between emotion terms and color affect our perception and responses to color.

Keywords: Stroop task, emotion, focal color, nonfocal color

Influence of Emotion on Color Perception

The perception of color spans many fields of study (e.g. biology, psychology, linguistic, psychophysiology, art). It is important to begin any research within this topic with an understanding of the development of theories of color, which then permit a comprehension of the biological and physiological perspectives of color vision. The biological and physiological perspectives explain universal concepts of the human framework of color vision. These universal concepts then allow other perspectives to explain that the differences in color perception among individuals results from differences in environmental rather than natural causes. These claims are made with the assumption that the individual has no biological visual impairments, deficiencies, or disorders. These environmental factors, such as language and culture, not only influence the perception of color, but also create associations between other concepts, such as emotion. This aim of the research is to understand how these emotional associations affect the perception of color.

Newton (1704), in his work *Opticks,* analyzed and explained properties of color in relation to the physics of light from perspectives of physical science. Newton observed that particles of light are refracted as the light passes through different media, such as light passing through air and then passing through water. The different media through which the light passes causes the particles to refract, in which they change direction as the media through which they pass change in density. This change results in a dispersion of particles, displaying a spectrum of colors which are created as the wave formations of the particles of light differ in frequency and result in a variety of hues. This spectrum allowed for a differentiation between colors. Through these experiments, Newton concluded that color is a visible physical property of light as it was seen that hues become visible through dispersion of light. He explained that this occurs because hues are compositions of varying frequencies of waves of particles of light. The wave-like properties of the particles of light lead to a major debate. Supporters of the Corpuscular theory of light (e.g. Gassendi, 1658, Hobbes, 1651 Boyle, 1661, Newton, 1704) suggest the idea that light is composed of minute particles. The opposing view supported the theory that light was composed of vibrating waves (Huygens, 1690, Young, 1804, Descartes, 1637, Hooke, 1665). Huygens (1690) proposed the theory that light is composed of waves that vibrate perpendicular to the direction in which the light was traveling and when passing through media, these waves can be bent, resulting in the waves spreading apart causing hues to differentiate, which is called diffraction. Though these views disagree, each view displays the characteristic that the color spectrum is a resulting factor of the refraction of light.

While physics approaches color as a result of properties of light, other perspectives provide insight for the human perception of color. Goethe (1810), in his book *Theory of Colours*, differed from Newton and established his own theory of color, focusing on the role and influence of human perception as a contributing factor to color vision, extending the perspective of human vision beyond the concepts of physics and adding a physiological approach. Goethe approaches his theory through a series of experiments that focus on the human experience of color. A primary factor of his theory focuses on the properties of color influenced by both light and dark and the resulting spectrum of color produced in each. This disputes Newton's theories that color is dependent on light, whereas Goethe proposes that both darkness and light together create spectrums of color. Newton devised a wheel from the resulting colors of light dispersion, and Goethe presented his own wheel, designed on a chromatic scale formed in a described natural order. This order is formed by a symmetrical process in which he proposes that colors on opposing sides of the wheel in diametrical relation demand the existence of the other as they are reflective compounds. As Goethe presented the physiological perspective that color perception is reliant on the experience of color, he presented characteristics that he associates the colors on his wheel and therefore initiates an approach to a psychophysiological connection between the presence and perception of color. While Goethe's theory of color is guided more by experiential approaches rather than objective, his theories provide insight into the complexities of color perception that are dependent upon an individual, and extending beyond physical properties of the colors. These theories form the bridge of between psychological and physiological perspectives on color.

Helmholtz (1850) studied the concept that there were three forms of photoreceptors within the eye and that each responded to only specific ranges of wavelengths of light. His psychophysiological perspective suggested that these photoreceptors then transmitted signals to the brain to create a perception of color. In defining the three types of photoreceptors, he suggested that there were receptors that responded best to short wavelengths which would transmit a blue color, a second group that responded best to medium wavelengths, transmitting a green color, and a third group that responded best to long wavelengths, which would transfer a red color. These photoreceptors work in combination to transmit a large variety of colors. Helmholtz provided evidence for this theory in a series of experiments. Within these experiments, participants were presented with a color that they needed to match by manipulating wavelengths of light. In one experiment, participants were presented with only two wavelengths of light, in which they were allowed to only transmit two of the three options of small, medium, or long wavelengths, and in another experiment, participants were presented with all three wavelengths of light including small, medium and long wavelengths. It was found that the participants needed lights representing the three wavelengths of colors to produce matching colors. From these experiments, Helmholtz deducted that the cones in the eye follow the same concept, and need only three types of photoreceptors to receive the three ranges of light wavelengths to transmit and perceive colors. This theory became known as the Trichromacy theory as well as the Young-Helmholtz theory.

While this connected physics of light with the physiological perception of color, Karl Hering (1892) proposed that there were some concepts that could not be fully supported on the claims of the Trichromacy theory. Hering suggested that some colors are opponents to one another as they do not combine to form intermediate colors. For instance we can see a bluish-green but not a reddish-green color. These opponent colors (red-green, blue-yellow and black-white) can be seen in afterimages, images that continue to appear after the presentation of another image is removed. Hering noted that colors that appear in these afterimages are composed of the opponents of the colors that appeared in the original image. He suggested that rather than having three photoreceptors that only respond to three ranges of light wavelengths, there are instead receptors that respond to opposing color pairs, suggesting that some colors do not appear together as he explains that the receptors can only receive one of the colors at a time. The control of response is determined by opponent neurons which when presented with a particular wavelength of light have either an inhibitory or excitatory response. These opponent neurons control which color in the pair responds to the wavelength as it excites the response of one color while inhibiting the response of the other. This theory suggests that the photoreceptors transmit only the differences of responses to the wavelengths, which is opposed to the Trichromacy theory that suggests that the wavelengths are transmitted in combination. It is now accepted that the processes suggested in these theories operate cooperatively, though in different areas of the nervous system, eye, and brain.

Light, as it is reflected from an object to the eye, is passed through the cornea, which then refracts the rays through the pupil. The regulation of the amount of light allowed to pass through the eye is controlled by the pupil. The light that is transmitted through the pupil is then passed through the lens, which refracts the rays on the retina at the back of the eye, where receptors are located. Schultz (1866) suggested an explanation of color vision that focuses on the functions of these receptors and developed what is known as the duplex theory of vision. This theory proposes that the visual system contains two groups of receptors within the retina of the eye. The first group of receptors are known as cones, which respond to color wavelengths when operating in settings with high illumination, which is also classified as photopic vision. The second group of receptors are known as rods, which operate in settings of low illumination and are not sensitive to color wavelengths, classified as scotopic vision. Wald (1964) used techniques to measure the absorption spectrum of the photopigments contained within cones. He helped provide evidence for the trichromatic color vision theory by identifying three different types of cone photopigments that were sensitive to only certain ranges of wavelengths. Each cone type contains photoreceptor proteins that absorb only specific ranges of light. Together, cones respond to their specialized wavelengths and in combination provide a spectrum of colors that can be perceived by the human eye.

The information received by these photoreceptors is then passed on through the ganglion cells that transmit the information to the optic nerve, which then begins the psychological connection to perception of color. From the optic nerve, the information is sent along the optic tracts and then enters the lateral geniculate nucleus, where layers of cells process different information. The parvocellular layers process color and structure, while the magnocellular layers process contrast and motion. These cells then project to the visual cortex, where research by Zeki (2005) proposes primary functions for each area. The primary visual cortex (V1) and secondary visual cortex (V2) are composed of different cells that each respond to different colors and forms, which are then transmitted to the third visual cortex (V3). The third visual cortex responds to form, but not color, whereas the fourth visual cortex (V4) responds to color, but not form.

Feldman (2013) questions Zeki's functional specialization of these areas, posing the binding problem. How does information from these different areas become integrated to form a cohesive visual perception? It is within this binding problem that differences in psychological perception arise. In response for the binding problem, the linguistic relativity debate is proposed to explain the influence of language and its effect on the perception of color. That is, language processing in the brain may be the way the different components of color and form are integrated.

A linguistic perspective on color perception, though, raises more questions. The principle of linguistic relativity, also known as the Sapir-Whorf hypothesis, suggests that the constructs of language affect the cognitive processes, including color perception, of the speakers of that particular language. This principle was developed Benjamin Whorf, who was mentored by Edward Sapir. Whorf (1937) studied the Hopi language, and found significant differences in the framework in which the Hopi language conceptualized time in comparison to the conceptualization established in the English language. Whorf proposed that the absence of grammatical constructs to express and define time in the Hopi language affected the perception of the Hopi people. He hypothesized that differences in language and culture affect the way people cognitively perceive and discuss the world around them. Malotki (1983), however, showed that the Hopi *does* contain constructs that form the perception of time which undermine Whorf's hypothesis of linguistic relativity. In defense of linguistic relativity, Dinwoddie (2006) argued that although there are constructs of the Hopi language that form concepts of tense and time, they are not perceived identically to perceptions formed by the English language.

Brown and Lenneberg (1954) applied the principle of linguistic relativity to the perception of color. They sought to understand how speakers of a particular language used the language to both categorize and recognize colors. The participants of the experiment were presented with colors and were asked to respond with the name of the color. In a second experiment, participants were exposed to colors, and were then asked to identify those colors from a large array of colors. After the task, the participants were asked to explain how they kept the colors in memory in order to select the proper colors from the given array. Participants responded that they named the colors upon exposure and kept those names in memory to select them from the array. The findings of the research support the idea that lexical differences are indicative of cognitive differences. They found that the codability of a color and the efficiency in naming a color were related to the ability of the participant to recognize the color. This suggests that the linguistic representation of stimuli has an effect of the cognitive process of retrieving and perceiving stimuli.

In opposition to the linguistic relativity principle is the universalist theory, suggesting that there is a universal categorization and development of color terms. The most notable research has been done by Berlin and Kay (1969) in what is known as their world color survey. Their work began as a search to identify the basic color categories that all languages utilize. Using field workers to collect data, representatives of each of the languages being studied were presented with tasks that aimed at the identification of color terms that were used in the language. To be considered a basic term required meeting specific criteria, ensuring that the reports only included terms that were representative of the language. Criterion included color terms being monomorphic, meaning that the word is composed of only one morpheme, monoleximic, meaning a singular meaningful linguistic unit, a singular representation of a color, representative of more than a singular class of objects, and utilized by all speakers.

Berlin and Kay found a cumulative process of developing basic color terms resulting from a cultural evolution of language. All cultures begin with the basic terms for black and white, and in each consecutive stage of a culture, new terms are added until the development reaches the final stage in which they identify a maximum of 11 color categories: black, white, red, green, yellow, blue, brown, purple, pink, orange, and gray. These stages are developed as follows. The first stage is a basis for all languages and contained terms for black and white (or dark and light). Within the second stage, the language develops a term for the hue red. In the third stage, the languages develops a category and term for either the color green or yellow, though not both. In the fourth stage, both green and yellow become terms in the language. Within the fifth stage, there become six color terms as blue is introduced. An introduction of the term for brown indicates the sixth stage. In the final stage, terms for purple, orange, gray, and pink are added. Berlin and Kay concluded that there was an existing basis for universal color perception as they concluded through their results that the languages they observed in their world color survey consistently followed this pattern of color term development.

Davies and Corbett (1997) analyzed the patterns of color grouping by speakers of English, Russian, and Setswana. These languages were chosen to be researched as they each differed on their defined color terms and on boundaries of color regions of blue and green. They examined the similarities between the groupings of these colors as well as patterns of systematic differences. The researchers wanted to determine whether the number of terms in the language affect the grouping of colors and whether the linguistic effects on color groupings rooted in differences in terming similar hues of colors. Participants in the study were given five tasks: a list task, in which participants were to list as many color terms as they knew, a free-sorting task, in which participants were to sort colored tiles into groups, a forced-sorting task, in which the experimenter presented an order of colors and asked the participant to match the colors, a City University Color Vision Test, in which participants were given 10 color plates arranged with a central color spot and surrounding color spots and were asked to choose which of the surrounding color spots is most similar to the central color spot, and a color naming task, in which participants were asked to give names for the colored tiles presented. The results of their study suggest that there are similar overall patterns, though there were some structural and categorical differences. Russian speaking participants established three dominant categories to distinguish the blue-green region, English speakers established two, and those who spoke Setswan only established one color category. They suggest the possibility that the learning of the language can affect the perception of the color, though results did not directly imply that their categorizations were reliant on the use of linguistic functions.

To approach the debate from a non-linguistic perspective, Kessen, Bornstein, and Weiskopf (1976) used infants that were in a developmental stage prior to language acquisition and presented the infants with basic colors. The aim of the study was to examine the perception of hue in children before they are capable of utilizing language and before being taught categorizations of color and to understand how categorization affects language learning and whether the patterns resemble those of adults. Infants were presented with a wavelength of light that possessed similar and dissimilar characteristics of hue and saturation. The amount of time that the infants spent looking at the colors as well as the amount of time it took for the infant to habituate to the stimuli were measured to provide inferences for how the infants perceived the colors. If the stimulus is perceived by the child to be different from the initial stimulus presentation and the child has an increase in time for looking at the stimulus, it can be understood that habituation has not occurred. If the child spends less time viewing the second stimulus, it can be inferred that the infant perceives the second stimulus to be similar to the first and as a result spends less time viewing the color, indicating that the color has been habituated. If the infant spends less time looking at the stimulus, it is a result of habituation, indicating that the child perceives the colors to be similar and indicates a categorization of colors. In a second experiment, infants were placed in three experimental groups that presented wavelengths that were either the same, from the same hue category, or were from different hue categories. The attention measurements were the same as used in the first experiment. Infants do display characteristics similar to those used after the onset of language acquisition and linguistic influence. The results indicate that infants created boundaries of color categorization for wavelengths that follow the blue-green boundary as well as green-yellow and yellow to red boundaries. The infants did not create a categorization for violet. This resonates with the biological perspectives that there are natural categorizations for perceiving categories of color suggested in the trichromatic color theory. The relevance of the research highlights the similarity of human development with respect to color categorization without the influences of language. The capability of the infants to develop a form of categorization for colors independent of the use of language it is clear that color categorization is a biological development that is universal.

To understand the connections implied by both theories, Heider (1972) used another method to investigate the linguistically relativistic effects of how language influences thought and perception of color. Heider used focal colors, which are colors defined as being best representative of eight chromatic color groups along with the three achromatic color groups (white, black, and gray), also known as the basic color groups.

Heider compared focal colors to nonfocal colors, which are those that are not best representative of one particular color group, such as colors that are viewed as being between color groups, like brick red or mustard yellow. In the first experiment, Heider presented an array of colors to participants in two groups. The first group was exclusively English-speaking, while the second group was composed of bilingual speakers of English and one of 10 other languages. These participants were asked to select colors, from the array of Munsell color chips, which best represented the basic color terms in each of the languages. They found that the most saturated color chips were the best representatives for both English and the other languages represented. In the second experiment, Heider studied whether these defined focal colors were the most codable across the languages through measurements of length of name and response latency of naming. She also hypothesized that the focal colors would be more codable than the nonfocal colors as defined by Berlin and Kay (1969). In Heider's second experiment, participants were presented with Munsell color chips and were asked to provide terms in their native language to represent each color. The time of response was measured. The results suggest that the codability of the word affects the speed of response to the word. Focal words with shorter names were named most rapidly and were most accurately recognized. There was a memory advantage for focal colors in comparison to nonfocal colors. In the third experiment, participants were grouped into two different categories, native English speakers, and those who spoke the language of the Dani, an Indonesian New Guinea people group. Participants were presented for 5 seconds with a color chip. After a time delay of 30 seconds, the participant was then provided with an array of color chips and was instructed to select the color chip that matched the previously presented color. For each presentation, the array was rearranged so as not to provide a memory tactic. The response times to select the matching colors were measured. The results suggest that memory accuracy was higher for focal colors than for nonfocal colors in both the American and Dani people. In the final experiment, a group of Dani people were required to learn a set of stimulus-response pairs where a color was paired with a separate response word. The participants were then presented with the color chips, and were asked to respond with the corresponding response word. This was repeated five times each day until the participant could perfectly master the task. The results suggest that focal colors were associated with words faster than nonfocal colors. Accuracy was also greater for focal words suggesting that focal words were directly connected with one specific color. This research not only implies that there are basic focal terms within languages, but that these terms can differ across languages.

To understand the cognitive processes involved with color and word perception, Stroop (1935) suggested that increased reaction time to words as a result of presenting stimuli in contradictory colors can be used as a measurement of interference in perception. In the first study, half of the participants were presented with a sheet of paper which listed names of colors presented in colored ink that differed from the color of the word and were then presented with a sheet of paper which listed names of colors printed in black ink. The other participants were presented with the same task, but the order in which the sheets were presented was reversed. The participants were asked to read the lists as quickly as possible, and the time for completion was recorded. The results suggested no significant differences in reading time between words printed in colors or black ink.

In the second experiment, Stroop gave participants two sheets of stimuli as before. Half the participants received stimuli in which they were asked to name colors that were presented in solid squares, then were presented with a sheet in which color words were presented in ink that differed from the word presented. The participants were asked to reply only naming the color of ink and not the word. The other half of the participants received the same tasks, but the order was changed to counterbalance the results. Stroop found interference between the habit of calling words and the naming of colors as responses were slower for the color of the ink when the words and color were incongruent.

In a third experiment, participants were presented with the same tasks listed in the previous experiment, but the participants completed these tasks repeatedly over the course of two weeks. This experiment was conducted to analyze the effects of practice on response times. The results of the practice trials suggest that practice increases individual differences for trials in which the participants had displayed a habituated pattern in that a learning curve persisted as the amount of successive days of trials increased. It was also found that when the ink color did not match the color name, there was an interference between the color and the word. When the color presented was incongruent with the word presented, the responses of the participant to the word was much slower than if the color ink in which the word was presented was congruent. This suggests that the color of the ink affects the perception of the word. The interference that occurs is a result of the source of the materials themselves as the stimuli are both presented visually. Because the stimuli are conveying different information, there is a slowed reaction to understanding the presentation as the information conflicts. These experiments combine ideas about the mental processing of color stimuli in relation to color names on recognition, speed and accuracy. The delayed responses to the stimuli of differing color ink and color names indicate that the compound stimuli increase cognitive load by presenting conflicting information, which activates more mental processes and slows reaction time. In turn, increased reaction time indicates more mental processes and greater cognitive load.

There are several theories to understanding how these differing stimuli are perceived and how they in turn create interference. Research by Dyer (1973) suggests that differences in response time may be a result of differences in the speed of processing for two different types of stimuli. For example, this would suggest that word processing is much faster than color processing. In a situation where both stimuli are presented at once, the faster form of processing will be received first, and therefore cause interference should the second stimulus be slower in processing speed. Within this experiment, participants were presented with cards that listed the words of colors in black ink in the center, along with a colored stripe. The participants were instructed to name the color as quickly and as accurately as possible. The reaction times were recorded. The reaction times were fastest for presentations in which the stimuli were congruent in comparison to trials in which the word and colored stipe were incongruent. Because there were significantly slower responses for trials in which the color and the word were incongruent, this suggests that the stimuli are processed at different speeds and therefore cause a slower reaction as the perceptions of the two stimuli interfere with one another.

The results suggest that the bilateral presentation of both word and color causes interference in perception as the word is processed with a faster speed than the color.

Another theory that attempts to explain the Stoop effect is known as the parallel distributed processing model, in which it is assumed that different tasks require processing through different pathways, and through practice, each of these pathways become stronger. Although this model is similar in concept to the automatic processing theory, it differs in that it considers the factor of attention (Cohen, Dunbar, and McClelland , 1979). Analyses of practice effects suggest that there exists a continuous interaction of interference and speed. The speed of processing and the interference effects should not be used on their own to explain automaticity as the pathways in which they are both processed have an effect on perception as well. Instead, three attributes of automaticity should be examined: the variation of strength as a function of practice, the relative strength of two competing processes and the observed interference effect, and how the strength of a process determines the extent to which it is governed by attention. Strength as a function of practice provides the idea that the more often a stimulus is presented and the response is practiced, the stronger the reaction will be and therefore automaticity will increase. The relative strength of the two competing processes affects automaticity as the stronger and more practiced stimuli will have a faster process and therefore be more automatized. The attention given toward stimuli also affects the processing of stimuli, as it requires attention to quickly process stimuli that are being processed, and stimuli that do not cause focused attention result in slower response times and are therefore less automatized. They also outline general characteristics of their proposed framework of processing. In regards to the construct of the processing, it is proposed that processing occurs in a network of connected modules in which each consists of small processing units which communicate input from other units while producing outputs. This sharing of inputs and outputs is presented as a pattern of activation which occurs by propagation of signals from one module to the next. As these signals continuously transmit information, the speed and accuracy becomes dependent upon the flow across an appropriate pathway. Interference occurs as information from several modules utilizes the same processing pathways. Dissimilar information causes interference among inputs and processing therefore becomes impaired. The aspect of attentional control is important as intentional focus can be used to control and avoid interactions through selective attention.

The final theory that attempts to explain the Stoop effect is known as automatic processing. MacLeod and Dunbar (1988) explain the idea that the Stroop interference as a result of interference between two automatized behaviors. Some cognitive processes become automatic: that they are rapid and do not rely on conscious cognitive functions. Automatic processing results from frequent encounters with stimuli. Other processes are known as controlled processes. They are often slower, as they are dependent on conscious processing and cognitive resources. In their first experiment, MacLeod and Dunbar presented trials with random shapes that varied in color, and were told to name the color. The participants were then presented with trials in which they were presented with the same stimuli, but instead were instructed to name the shape of the stimulus. The results indicate that colors with incongruent shapes were named more slowly than those with neutral or congruent shapes. The results also suggest that there was a significant increase in interference with practice.

In a second experiment, participants were exposed to the same trials, but instead repeated these tasks over the course of five days, and after 3 to 3.5 months, the participants were contacted to perform the tasks again. The results found that over the span of time, the participants did not increase speed at the expense of accuracy. The major finding was that there was an emergence of interference in color naming as a result of practice in naming trials. This suggests that shape naming became more automatic as practice increased.

In the third experiment, participants followed the same tasks as outlined in the previous trials, but the practice training was extended over the course of 20 days. The results of the three experiments suggest that there is a pattern of interference and facilitation that depends on the amount of practice the participants had with each task. The results further suggest that as automaticity increases, the cognitive processes for perception become more comprehensive and integrated.

Wexner (1954) suggested that relations between color and emotional states exist and devised an experiment to determine to what degree colors (hues) are associated with mood tones (words labeling moods). Some colors are associated with certain moods more than other colors. The participants of the study were instructed to select color chips and match these colors with mood-tones that were presented. The colors could be used more than once and not all the colors had to be used, though a color had to be selected for each mood-tone. The frequencies of matches between colors and mood-tones were measured. The results indicated that certain hues were associated with specific mood-tones, though some associations were stronger than others. For instance the following color-mood tone associations were paired significantly more frequently: red-exciting, stimulating; blue-secure, comfortable, tender, soothing; orange-distressed, disturbed, upset; purple-dignified, stately; yellow-cheerful, jovial, joyful; and black-powerful, strong, masterful. These associations indicate that emotional connotations of color may affect the way humans perceive color.

Theories of color perception processing often focus on the differences in perception of color presentation and word presentation, but Wexner's research suggests that the emotional aspects associated with colors may influence speed of processing and perception as well. To study the emotional connection of color, Valdez and Mehrabian (1994) investigated emotional reactions, of pleasure, arousal, and dominance to hue, defined as the wavelength of light, saturation, defined as the purity of vividness of the color, and brightness of colors, defined as the black-to-white quality.

Within the first experiment, participants were presented with 7 color samples of the same hue that varied in brightness and saturation for 10 different hue groups (red, yellow, green, blue, purple, yellow-red, green-yellow, blue-green, purple-blue, and red-purple). The participants were to respond to the presentations using a devised pleasure, arousal, and dominance (PAD) scale that evaluated the participants' perceptions of pleasure, arousal, and dominance as caused by the color presentation. On this scale, each dimension has two levels, either positive or negative (pleasure-displeasure, arousal-non arousal, and dominance-submissiveness) that can be used to describe an emotional state as the combinations of each aspect vary in respect to one another. The hue categories of blue, blue-green, green, purple-blue, red-purple, and purple were viewed as most pleasant, whereas the hue categories of yellow, green-yellow, and red-yellow were rated to be the least pleasant. There were weak results supporting associations between hue and ratings of arousal and dominance.

In the second experiment, participants were presented with color samples that had equal brightness and saturation, but displayed differences in hue, and the participants evaluated their perceptions of pleasure, arousal, and dominance using the same scales as the previous experiment. When colors varied in hue, saturation, and brightness, the colors were emotionally perceived differently. For example, colors that were high in color saturation were rated as being more arousing. Ratings of dominance also decreased as the brightness of the color increased. Ratings of pleasure of a color were a joint positive function of color brightness and saturation, and ratings of arousal correlated with color saturation. Different colors ranged in characteristics of hue, saturation, and brightness leading to varied perceptions of pleasure, arousal, and dominance in accordance with the model. Results suggest that when color composition varies, so do emotions.

The various perspectives that explain the perception of color can be combined to understand the influence that emotion has on color perception. As the biological model of color vision is universal, the observed differences in perception rely on explanations of other perspectives, such as the way our language shapes the way we process color stimuli and how the emotion terms in our language can influence how we perceive colors. Frequent usage and associations between color terms and the corresponding hues may produce automatic processing, and even further, frequent interactions between emotion terms and specific hues may influence processing and affect the perception of color.

The purpose of the present study is to evaluate the associations that occur between variables such as congruence, whether the presentation of a word matches the color in which it is presented; associations between terms, emotion or color, and color presentations, either focal or nonfocal. Through the use of a modified, computerized Stroop task, both emotion and color words (the emotion words as defined by Wexner (1954) and basic color terms as described by Berlin and Kay (1969)) were presented in either congruent or incongruent colors. These colors will also differ on whether they are presented as focal or nonfocal colors, as defined by Heider (1972). The aim of the study is to evaluate the influence that emotion associations have on the perception of color, as measured by response time.

Several hypotheses have been developed. First, I hypothesize that participants will respond faster in the color name trials compared to emotion word trials, as participants will most likely have a higher automatized association for color and color names compared to colors and emotion words because people encounter associations between color and color names more frequently than colors and emotion words. As described by the automaticity theory (MacLeod and Dunbar, 1988), color word and colors are more often presented simultaneously together, resulting in more practice, and therefore strengthening the processing for congruent color and color word associations. Emotion word and color presentations are encountered, together less frequently than color-word associations. Fewer stimulus presentations lead to less practice, and in turn result in a lower speed of processing measured as response times.

The second hypothesis is that when emotion words are presented in the color with which they are associated, participants will respond faster than when the emotion words are presented in colors with which they have no association. If there is an automatized behavioral response between corresponding emotion words and colors, then presenting emotion words with unassociated colors would cause interference in perception. As described by the parallel distributed processing mode (Cohen, Dunbar, and McClelland, 1979), congruent emotion word- color pairs will have similar processing pathways as they are related to one another (Wexner, 1954), and as a result this would increase the speed of processing and therefore lead to faster responses. Associations between emotion words and non-associated colors are less likely to be processed together and should cause an interference effect. The stimuli would cause two separate pathways to be engaged, producing interference in perception and a decrease in reaction time.

The final hypothesis is that responses will be faster for emotion word and color associations when the emotion words are presented in focal colors rather than nonfocal colors. Focal colors are best representative of the color and would have a higher automatized perception and lead to faster association, which would allow faster responses. As Heider suggests (1971), focal colors are the best representative for each hue group, and as a result are encountered more often, leading to increased use of processing pathways, which therefore lead to faster reaction times (MacLeod and Dunbar, 1988).

Method

Participants

A total sample of 37 undergraduates, 9 male and 28 female, at Houghton College were obtained from a pool of participants. Data from 6 participants (4 male and 2 female) were excluded from all analyses because 4 reported English was not their first language, 1 participant was color-blind, and 1 participant failed to complete the task. All participants were assigned to perform the same task sequence in a repeated measures design.

Apparatus

A 17inch LCD Acer monitor, model #AL1706A, was used to present the stimuli on a standard Windows operating system. Participants sat in front of a computer workstation so that the approximate distance between the participants' eyes and the computer screen was 70 cm. Participants responded to the stimuli by pressing specified keys located on the keyboard and the reaction times (RTs) were recorded by key-press. Brightness was controlled through monitor settings. The room was lit by overhead florescent lights and blinds were drawn over the windows to prevent interference from external light sources.

The experiment was programmed using Superlab Pro Version 4.5.

Stimuli

Stimulus presentations were composed of color and emotion (also referenced as mood-tone) terms presented in both focal and nonfocal colors. All stimuli were presented in lowercase, 20 point, Tahoma font, on a white background, and appeared in the center of the screen.

Color terms used in this experiment were those defined by Berlin and Kay (1969). Their research showed that the English language contains eleven basic color terms: white, black, red, green, yellow, blue, brown, purple, pink, orange, and gray.

Associated colors and mood-tones were as defined by Wexner (1954). Wexner provided several terms for each color association. Only one mood-tone (word) was selected to be associated with each color. This selection was made through analysis of both the length of the word and level of association. Mood-tones ranged in length of 6 to 9 letters, and only the strongest associated mood tone was used to be associated with each color. The following mood-tone and color associations were used: red-exciting, yellow-joyful, green-peaceful, blue-soothing, orange-disturbed, brown-unhappy, and purple-dignified. It should be noted that in Wexner's research, both blue and green were highly associated with the mood-tone *peaceful*. It was decided, for the purpose of this study, that green was to be associated with the mood-tone peaceful, as blue had higher associations with the mood-tone *soothing*.

The notations of focal and nonfocal colors for color terms were defined by Heider (1971) using the standard Munsell color system. Because the stimuli are presented through an electronic display, which does not utilize the Munsell color system, but rather an RGB color model, these Munsell color notations were converted to equivalent RGB color codes (Centore, 2013) , as detailed in table 1, which could then be used to present the colors in the computerized task.

Color	**Munsell Color Code**	**RGB Color Code**
Focal Colors		
Red	5.0R 4/14	189, 24, 55
Yellow	2.5Y 8/16	255, 189, 0
Green	7.5G 5/10	0, 142, 109
Blue	2.5PB 5/12	0, 127, 211
Orange	2.5YR 6/16	243, 107, 0
Brown	5.0YR 3/6	110, 58, 27
Purple	5.0P 3/10	103, 47, 127
Nonfocal Colors		
Red	5.0R 5/14	220, 63, 78
Yellow	2.5Y 6/12	193, 139, 0
Green	7.5G 3/8	0, 85, 65
Blue	2.5PB 7/8	125, 178, 238
Orange	5.0YR 5/12	190, 97, 0
Brown	2.5YR 4/10	160, 69, 20
Purple	5.0P 5/10	152, 102, 180

Table 1. The Munsell and RGB color codes for focal and nonfocal colors

For this experiment, the color terms and color presentations for white black, gray, and pink were excluded as previous research did not support their use. Wexner did not utilize the colors white, gray, and pink, and therefore there are no mood-tone associations in the literature. Heider did not include the colors white, gray, or black in her studies and therefore provided no Munsell notations for their focal and nonfocal presentations.

In the present study, white and black were excluded as the color of the background the stimuli were presented on was white and the instructions were presented in black color.

Design and Procedure

A 2 (Congruency: congruent, incongruent) x 2(Color Presentation: focal, nonfocal) x 2(Term: emotion, color) within-subjects, repeated measures design was used. This design creates eight conditions, as detailed in table 2.

	Congruent		**Incongruent**	
	Focal	**NonFocal**	**Focal**	**NonFocal**
ColorTerm	Congruent Focal Color (CFC)	Congruent Nonfocal Color (CNC)	Incongruent Focal Color (IFC)	Incongruent Nonfocal Color (INC)
Emotion Term	Congruent Focal Emotion (CFE)	Congruent Nonfocal Emotion (CNE)	Incongruent Focal Emotion (IFE)	Incongruent Nonfocal Emotion (INE)

Table 2. The eight conditions in the 2x2x2 factorial design.

The tasks were adapted from Stroop (1935). Participants were tested individually. Prior to presenting the instructions for the task, participants were tested for color vision deficiency as well as their ability to define colors with color terms using Dvorine Pseudoisochromatic Plates. The experimenter then explained the instructions for the task. Participants were told that they were to indicate, using specified computer keys, “y” for yes and “n” for no, whether the word presented matched the color in which the word was presented and they were to respond to each stimulus presented as correctly and as quickly as possible. Before beginning the task, the experimenter explained and presented, visually and verbally, the associations between color terms and colors as well as between emotion terms and colors as well as providing examples of these associations. The participants were informed that these associations would be used in the task and they should take as much time as needed to familiarize themselves with the associations.

When participants indicated that they understood the associations, they were seated approximately 70cm from the computer screen and were instructed to begin the task.

The task was designed in two blocks, each containing two randomized sections. Each block began with a reiteration of the instructions as well as an example of each. For each section, participants were given a practice session with 14 trials of congruent term and color stimuli, as well as 14 trials of incongruent term and color stimuli. In the first block, participants were presented with color terms that varied in the colors in which they were presented. In the first section the color terms were presented in focal colors, and in the second section, the color terms were presented in nonfocal colors. In the second block, participants were presented with emotion terms that varied in the colors in which they were presented. In the first section the emotion terms were presented in focal colors, and in the second section, the emotion terms were presented in nonfocal colors. In each section, the participant was presented with 42 trials of congruently paired term and color stimuli as well as 42 trials of incongruently paired term and color stimuli. For incongruently paired terms and color stimuli, each term was paired with each incongruent color once. For congruently paired terms and color stimuli, each term was paired with their associated congruent color six times. The stimuli remained on the screen until the participant made a response through key-press.

Results

Mean RTs were computed for all responses for each participant for each of the eight experimental conditions (CFE, CFC, CNE, CNC, IFE, IFE, INE, and INC). The RTs for the practice trials were excluded. The RTs for all trials were included in the computations. These means were then examined with a 2 x 2 x 2 (Congruence [congruent, incongruent] x Color Presentation [focal, nonfocal] x Term [emotion, color]) within-subjects analysis of variance (ANOVA) A single between-subjects variable (Gender [male, female]) was included.

The results revealed significant main effects of congruence, color presentation, and term on reaction time. The RTs for congruent trials were significantly faster (*M* = 1173.004) than for incongruent trials (*M* = 1304.430), $F(1, 29) = 26.227$, $p = .000$, $\eta_p^2 = .475$, and had a moderate effect size. The RTs for focal color trials were significantly faster (*M* = 1156.438) than for nonfocal color trials (*M* = 1320.997), $F(1, 29) = 27.510$, $p = .000$, $\eta_p^2 = .487$, and had a moderate effect size. As hypothesized, the RTs for color term presentations were significantly faster (*M* = 1084.536) than for emotion term presentations (*M* = 1392.899), $F(1, 29) = 48.663$, $p = .000$, $\eta_p^2 = .627$, with a large effect size.

The results also indicate that there was a significant interaction between congruence and color presentation, $F(1, 29) = 7.162$, $p = .012$, $\eta_p^2 = .198$, suggesting, as shown in Figure 1 and Table 1, that the difference between congruent and incongruent presentations was greater for focal color presentations than for nonfocal color presentations and displayed a small effect size.

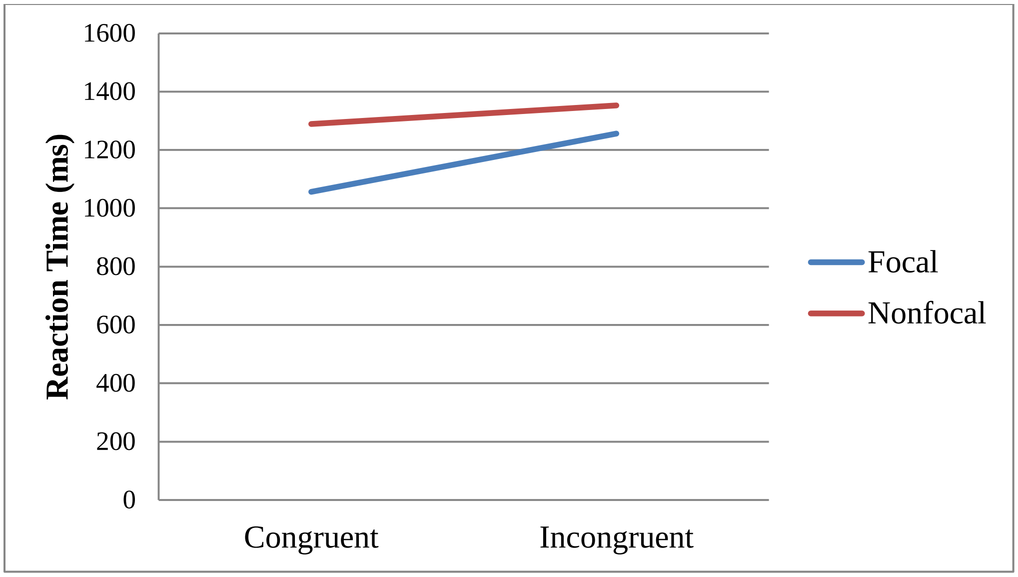

Figure 1. Interactions between Congruence and Color Presentation

Congruent		Incongruent	
Focal	Nonfocal	Focal	Nonfocal
1056.434	1289.574	1256.441	1352.420

Table 1. Mean Reaction Times (ms) of Congruence and Color Presentation

There was also a significant interaction between congruency and term $F(1, 29) = 20.929$, $p = .000$, $\eta_p^2 = .419$, suggesting, as shown in Figure 2 and Table 2, that the difference between congruent and incongruent presentations was greater for emotion term presentations than for nonfocal color presentations and has a moderate effect size.

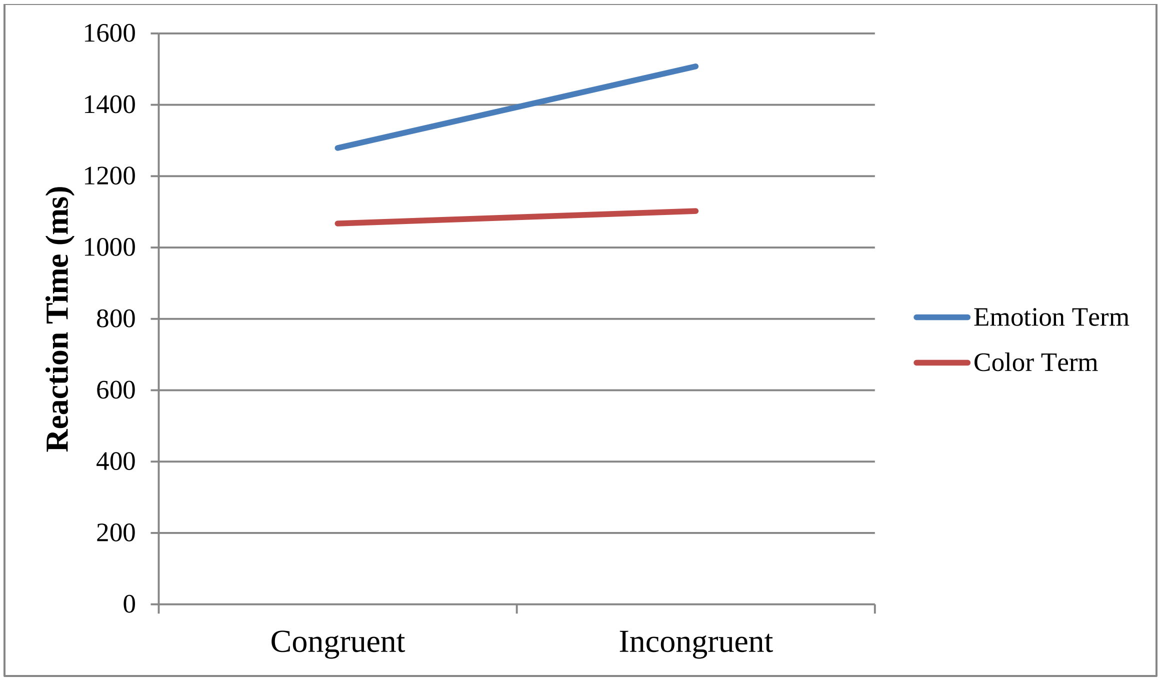

Figure 2. Interactions between Congruence and Term

Congruent		Incongruent	
Emotion Term	Color Term	Emotion Term	Color Term
1278.787	1067.221	1507.011	1101.850

Table 2. Mean Reaction Times (ms) of Congruence and Term

Though RTs were faster for color terms when presented in their focal colors, there was not a significant interaction between color presentation and term, $F(1, 29) = .979$, $p = .331$, $\eta_p^2 = .033$.

There was a significant three-way interaction among congruence, color presentation, and emotion term, $F(1, 29) = 5.373$, $p = .028$, $\eta_p^2 = .156$. The differences between congruent and incongruent presentations was greater for focal presentations than for nonfocal presentations, with a greater difference when presented as emotion terms than for color words and has a small effect size, as seen in Figures 3 and 4 and in Tables 3 and 4.

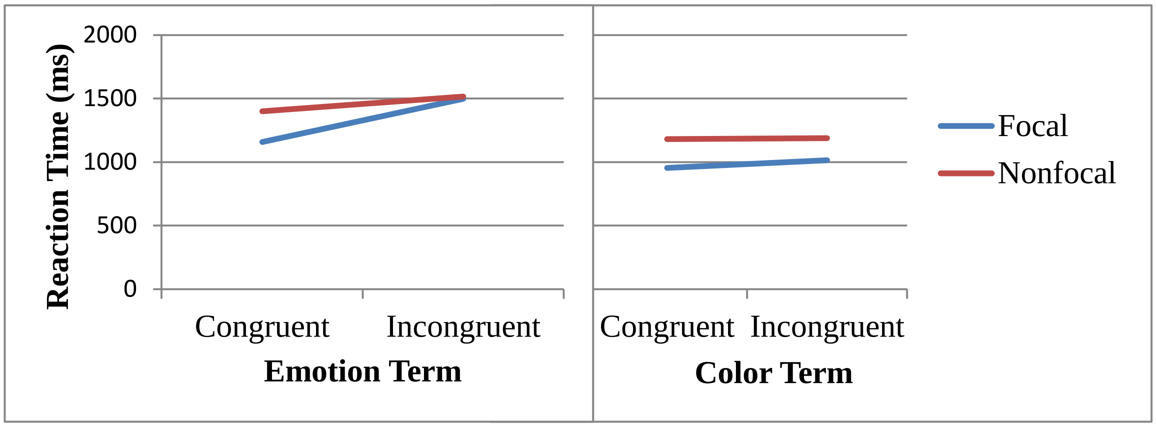

Figure 3. Interactions between Congruence, Color Presentation, and Emotion Term

Emotion Term			
Congruent		Incongruent	
Focal	Nonfocal	Focal	Nonfocal
1158.354	1399.220	1497.381	1516.641
Color Term			
Congruent		Incongruent	
Focal	Nonfocal	Focal	Nonfocal
954.515	1179.928	1015.501	1188.199

Table 3. Mean Reaction Times (ms) of Congruence and Color Presentation for Emotion and Color Terms

There were no significant main effects or interactions for gender.

Discussion

Responses on congruent trials were significantly faster than on incongruent trials. This suggests that there is an automatized response for both congruently matched color and emotion words with their associated colors, supporting the theory that the associations are often encountered and created a parallel processing network.

The results also suggest that reaction times for focal color trials were significantly faster than for nonfocal trials, supporting the hypothesis that focal colors are best representative of hue groups, and therefore are more likely to be utilized to represent associations between colors and emotion terms. In support of the stated hypothesis, reaction times for color term presentations were significantly faster than for emotion term presentations. This finding may be an indication of the automaticity theory, suggesting that emotion term processing may not be as highly autotomized as color word processing, as the emotion terms may not be encountered as frequently and therefore result in slower processing.

The results also indicate that there is a significant interaction between congruence and color presentation. The superior speed of processing congruent pairs is greater for focal colors than for non-focal colors. This suggests that focal colors are best representative of hue groups, and as a result lead to faster responses as they are accessed more quickly as their processing network is stronger from higher frequency of use.

The results also suggest a significant interaction between congruency and term. The superior speed of processing congruent pairs is greater for emotion words than for color words, suggesting that there is a parallel processing for word associations with colors. As they are frequently presented together, their processing networks for both strengthen and create less interference and allow for faster response times.

Finally, the results support the hypothesis in that they indicate a three-way interaction between congruence, color presentation, and emotion term. From this, it can be understood that there was a larger difference for congruent focal presentations when presented in association with emotion words. This indicates that there is a strong association between the focal color associations and emotion words. The implications are that the processing networks for color and term when presented in congruent pairs are strong and have a highly automatized association as they display little interference and reaction times are faster.

The results in the study are consistent with those established by Stroop (1935) as responses were faster for stimuli in which the presentations were congruent. It can also be understood that presentations in emotion terms have similar effects, and in this case, the differences in reactions times for emotion terms were higher than for color terms. These findings have implications for the effects that emotion term associations have on color perception. Should these emotion terms have such high influence, it should be considered how these constructs of our language define our perception of our surroundings. As this research suggests that emotion term associations affect the perception of color, these associations may also affect our perception of colors as they arise in our environment. For example, use of colors to convey information is dependent on shared associations between emotion and color. Red is used to display awareness to others, such as in traffic stop signs and fire exit signs. Not only is the color red significant to indicate an exciting emotion, but it should be noted that the color red used to indicate this information is presented in a focal color rather than a nonfocal color. As these color and emotion word associations do exist, they can be utilized to further convey information and shape the perceptions of the world around us.

As emotion words, constructs of language, guide perceptions of color, it can be understood that these perceptions are limited by the language with which we communicate. As linguistic relativity affects our perception of the world around us, it should be considered that not all participants make the same emotion term and color associations. Also, as explained by Berlin and Kay (1969), language development affects the categorization of colors and not all language groups have the same hue categories of colors and this may affect how a particular language defines perceptions of color and creates associations between color and emotion as different categories may exist and therefore affect the possibility for associations to be made. In regards to the linguistic-relativity principle, the language constructs, such as emotion words, also differ across cultures. Emotion words may also affect the limits of associations to be made between emotions and colors as different languages may have varying emotion words which may also vary in association. A different research design for this experiment would require each participant to select emotion terms that they personally associate with specific color presentations. This may also increase the effect of automaticity. If the participant were to select terms that best represent their perspectives, it would reflect a stronger processing and higher automaticity, as the participant is indicating that they have created the associations and interact with them more often.

The same idea could be investigated with the focal and nonfocal colors. If participants select colors that they find to best representative of each hue, they may have a faster response time as they would more likely have a higher automaticity for the color and identify and code the color faster than by colors selected by the experimenter.

Further research should investigate these effects between emotion term associations and color presentations in other languages. The implications that emotion term and color presentation associations have in various languages and cultures may further indicate if the linguistic relativity principle has effect on the perception of color.

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