

The Influence of Color-Coded Words and Colored Backgrounds on Semantic Memory: An Experimental StudyNaba Noor, Ushna Nawaz¹, Muhammad Talha Khalid^{1*}, Rabia Rafique¹¹ Department of Psychology , Gift University, Gujranwala, Pakistan**Abstract**

The current experimental study aims to determine the influence of color on semantic memory retention. The objective of this study is to investigate the distinct impacts of different color backgrounds and color-coded words, particularly warm (red), cool (blue), and neutral (grey), on individuals' capacity to accurately recall information. The study used a repeated measure design to complete the study and included 60 literate individuals following the inclusion criteria. In the experiment, participants are shown a series of neutral words set against various background colors as well as words that have been color-coded. This is followed by a brief period of distraction. They are then asked to remember the words that they have seen (Recall 1 and Recall 2). Recall 1 is taken immediately, whereas recall 2 is taken after distraction. SPSS 27 was used to manage and analyze data. Repeated measure ANOVA is used to assess the differences across various color conditions. The study concludes that color influences memory recall greatly, with warm colors having the greatest influence. It is anticipated that the current research's findings would assist in understanding how color influences cognitive functions (memory), especially in educational settings.

Keywords: Semantic memory, Colored background, Color-coded words

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1. Introduction

Color is described as light reflected from things; it is commonly quantified in terms of hue, or the shade of a color, saturation, or the purity of a color, and brightness (Dai, 2023). A wide range of colors is present in this world, and each color has multiple shades. Human beings (without any sight disability) can see and enjoy different colors. Depending on the three different types of cone systems and the varying ratios of stimulation in response to different wavelengths, humans can detect hundreds of hues of color (Jaint et al., 2010). The brain receives about 80% of its information visually, and color is crucial to this process (Dai, 2023). However, different colors influence humans' cognition differently.

Usually, colors are categorized as warm colors, cool colors, and neutral colors. Warm colors are generally defined as those in the red, orange, and yellow range of the color spectrum, which have longer wavelengths and are associated with warmth, energy, and excitement. Whereas, cool colors are those in the green, blue, and purple range, which have shorter wavelengths and are associated with calmness, tranquility, and relaxation (Townsend, 2017). Neutral colors are defined as muted tones that seem colorless but frequently have underlying shades that shift depending on the illumination, for example, black, brown, and beige (Class, 2021).

The categorization of colors as "warm" and "cool" is relative, as the perception of a color's temperature can depend on the surrounding colors and context (Townsend, 2017). Research has shown that warm colors tend to advance toward the viewer, while cool colors recede, creating an illusion of depth (Bailey et al., 2006).

Color draws attention during the learning process more effectively than other visual characteristics (Diachenko et al., 2022). Smilek et al. (2022) explored how physical activity can enhance both short- and long-term memory, as well as the unique ways in which harmonic color contrasts with other colors might increase human memory function.

Given this, we can say that the materials' color has a significant influence on students' productivity as well; this accounts for students' preference for colorful visuals and the fact that they take less time to recognize colored items than colorless photos. In comparison to a colored object placed against a colored background, a colored object against a colorless background ensures a faster response time and improves memory retention (Wichmann et al., 2002; Zavarueva et al., 2022). One component of the learning environment that affects learning results is the color of the instructional materials (Luis et al., 2019). It has been observed that color has captivated academics for ages (Sloane, 1991; Gage, 1993).

Since Goethe (1810) wrote his Theory of Colors, which connected color categories (such as the "plus" colors of yellow, red-yellow, and yellow-red) to emotional responses (such as warmth and enthusiasm), theories regarding the relationship between color and psychological functioning have been around. Building on Goethe's intuitions, Goldstein (1942) proposed that specific colors (like red and yellow) elicit systematic physiological reactions that show up as negative arousal, overt action (like aggressive behavior), and cognitive orientation (like outward attention). Following Goldstein's lead, theories have concentrated on wavelength, suggesting that colors with longer wavelengths are stimulating or warm, whereas those with shorter wavelengths are calming or relaxing (Nakashian, 1964; Crowley, 1993).

Additional theoretical claims regarding the relationship between color and psychological functioning have centered on general associations that people have with colors and how those associations affect behavior, cognition, and downstream effects (black, for example, is linked to aggression and provokes aggressive behavior) (Frank &

Gilovich, 1988; Soldat et al., 1997). The influence of color on memory performance is believed to be related to the mood colors can evoke in the perceiver. However, cognitively and perceptually, males and females perceive colors differently and have different experiences with colors (Jaint et al., 2010). Warm colors like red and yellow may have a greater impact on males, while cool colors like blue could exert a stronger influence on females (Liu & Khan, 2020).

In addition, psychologists have utilized various color-coding strategies and color cues to detect and treat patients with language impairments, including dementia and autism, demonstrating the importance of colors in client care (Liu & Khan, 2020).

A study by Khan and his colleagues in 2020 found that warm colors like yellow can optimize learners' efficiencies in retrieving information and knowledge productivity, such as collocations and idioms, instantaneously. This study also highlighted the importance of reducing cognitive overload in the learning process through the strategic use of colors, particularly warm colors like red and yellow, which have been shown to have a greater impact on male participants (Khan & Liu, 2020).

However, another study on the impact of color on memory and cognition has also been explored in the context of educational settings. A study by Diachenko and his fellows concluded that colored objects are perceived, felt, and remembered better compared to objects of the same shape in gray-scale, drawing attention during the learning process more effectively than other visual characteristics.

Furthermore, researchers have found that the color red can, on its own, lead to an improvement of memory techniques for receiving achievement-related details, most probably by making the person feel an avoidance motivation (Elliot et al., 2007). In contrast, cool colors, i.e., blue, not only promote lateral thinking but also catch the global processing style, which may be advantageous to the long-term memory of the conceptual and relational information. These two sets of findings imply that the deliberate application of warm, neutral, and cool colors can exclusively augment different sections of the long-term memory and cognitive processing (Mehta & Zhu, 2009).

In addition, it is interesting that the use of different colors can have an impact on how students learn and remember information. It is evidenced that particular colors, such as warm colors (red, yellow), promote the interest of students and the improvement of memory, especially for the short-term recall, compared to cool colors. Also, the shades of the colors can generate entirely different emotional perceptions in students and, consequently, change their motivation and engagement. But the effects of color can also differ from one culture to another. Therefore, the instructional designers should consider the cultural differences when they are using colors in learning materials. Thus, the study demonstrates that the careful use of color in the academic text and design can assist the student in their learning and memorizing the material more successfully (Chang et al., 2018).

Another research explored the connection between color perception and memory performance. It was discovered that seeing red background color has more effect on attention span and short-term memory than blue or white backgrounds. However, they highlighted that the results could be affected by some confounding factors and proposed to carry out more research in this area (Jadho et al., 2020).

The essence of the prior studies is that color can be an important factor in how someone remembers and processes information. This is especially effective with specific colors, for instance, the warm-toned ones such as red and yellow, which also seem to help in acquiring both short-term and long-term memory. This could be due to the fact that color

has the power to elicit different emotions, which in turn affects the efficiency of the learning and the retrieval of the information. On the other hand, the influence of color is rather complicated; it varies to a great extent depending on several issues, including the individual's personality, sex, and cultural background. Though color does not always directly correlate with basic memory skills, it still may serve as a tool for the better function of the cognitive processes which are involved in memory and learning. This set of research implies that the deliberate use of color in educational and other settings is a potentially efficient way to improve attention, memory, and information processing in individuals. However, additional inquiries are still required in order to thoroughly grasp how color affects the brain and what determinants will affect the color's optimal positive impact. More experiments can teach us about the most appropriate applications of color in different situations to enhance learning and memory. Studies conducted in the past have indicated that distinct colors have an effect on cognition (Buechner et al., 2014; Jadhao et al., 2020; Saikia et al., 2023), but there has not been any research conducted on the influence of color on long-term memory retention.

Therefore, this study aims to investigate the influence of color on semantic memory performance. It is identified that previous research has focused on short-term memory, revealing that information presented in warm colors like red and yellow and cool colors like blue and green is more readily recalled compared to neutral colors. However, the effects of color on long-term memory retention remain less explored. Therefore, the current study is focused on examining how warm, cool, and neutral colors influence memory recall for words.

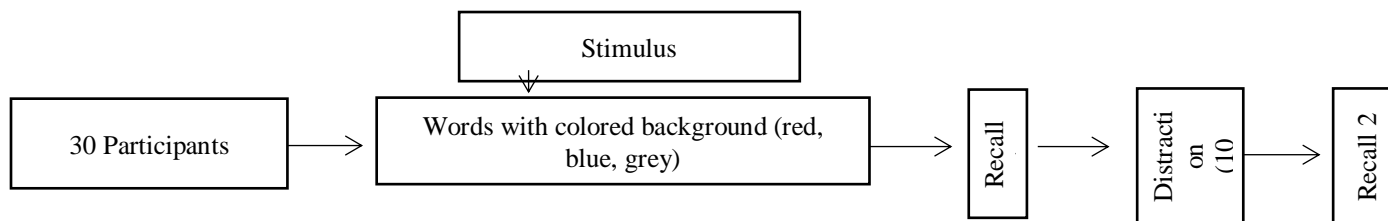
2. Method

2.1 Study Design and Variables

The repeated-measure design was used for the current study. The current study used three levels of independent variables: (1) Warm Color (Red), (2) Cool Color (Blue), and (3) Neutral Color (Grey). Memory Recall (percentage of the words that were accurately recalled) was taken as the independent variable.

2.2 Participants

Figure 1, Study Design 1



Note. Experimental Design for Study 1

Study 2

2.5 Material

One set of study materials, including 60 neutral color-coded words were used. The color of the study materials varies from warm to cool to neutral colors, but their words were the same.

2.6 Procedure and Protocols

Participants were selected following the inclusion criteria. Participants were asked about their eyesight and ocular condition. Before starting the experiment, the experimenter debriefed the purpose of the study, and informed consent was taken from the participants.

The sample consisted of 60 literate individuals (30 males and 30 females). The number of participants was selected by considering the sample size taken in previous studies. The participants were selected based on the inclusion and exclusion criteria. Only those individuals were selected who have healthy eyes and good eyesight with or without aid (such as glasses or contact lenses). Individuals who were unable to read and write English were excluded from the current study.

Study 1

2.3 Material

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In the first study, words with different background colors (warm, cool, and neutral) were shown through the projector or computer screen. Three levels of the independent variable and words were presented randomly to the participants. Each word was shown for 2 seconds, and the fixation mark stayed for 300 nanoseconds each time. After that, an immediate recall (recall 1) was taken from the participant on blank sheets. Later, to avoid the immediate rehearsal of the words, participants were involved in a distraction activity for 10 minutes. For distraction purposes, a cartoon video (SpongeBob SquarePants) was used.

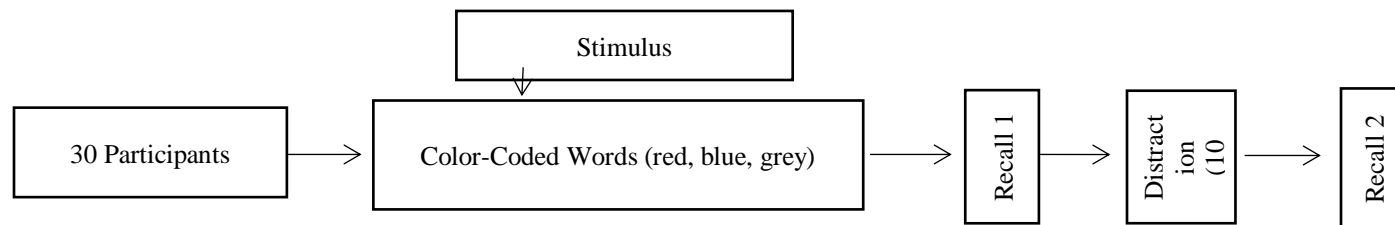
Later on, participants were given blank sheets of paper and were instructed to recall (write) as much information as they could within 6 minutes. For every participant, the number of correct words from the study material that they could recollect was noted. In order to control the extraneous variables, the experiment was performed with one individual at a time (one-to-one) in a closed room with no distractors. The computer screen was placed at an angle so the participants could see it easily. The words shown to the participants were of medium size, and a fixation mark was used to maintain the participants' attention.

In the second study, color-coded words (warm, cool, and neutral) were shown through the projector or computer screen. Three levels of the independent variable and words were presented randomly to the participants. Each word was shown for 2 seconds, and the fixation mark stayed for 300 nanoseconds each time. After that, an immediate recall (recall 1) was taken from the participant on blank sheets. Later, to avoid the immediate rehearsal of the words, participants were involved in a distraction activity for 10 minutes. For distraction purposes, a cartoon video (SpongeBob SquarePants) was used.

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extraneous variables, the experiment was performed with one individual at a time (one-to-one) in a closed room with no distractors. The computer screen was placed at an angle so the participants could see it easily. The

Figure 2, Study Design 2



Note. Experimental Design for Study 2

2.7 Data Analysis

SPSS 27 was used to complete the data analysis procedure. By using repeated-measure ANOVA (analysis of variance), the memory recall accuracy was evaluated.

3. Results

Table 1

Socio-demographic Characteristics of the participants (N=60)

Variable	Ovarian Cancer	
	N	%
Age		
15-20	10	16.6%
21-25	41	68.3%
26-30	09	15%
Gender		
Male	30	50%
Female	30	50%
Education		
Master's Degree	15	25%
Bachelor's Degree	38	63.3%
Inter	07	11.6%
Profession		
Student	45	75%
Job Holder	15	25%
Family System		
Joint Family	39	65%
Nuclear Family	21	35%

Note. Table 1 indicates the sample characteristics of our sample, n = number of participants, and % = percentage

Table 1 indicates the demographic characteristics of the participants. 60 participants were involved in the current study; among them, 16.6% of the ovarian cancer patients were from 15-20 age group, 68.3% were from 21-25 age group, and 15% were from 26-30 age group. In terms of gender, 50% were male and 50% were female.

In educational level, 25% participants had a Master's degree, 63.3% participants had a Bachelor's degree, and 11.6% participants were with inter degree. Regarding the professions of the participants, most of them were students, retaining 75% and 25% were job holders. In terms of family system, most of the participants live in a joint family system (65%), and 35% of the participants are part of a nuclear family system.

Table 2 indicates that there is a significant difference (F (2, 58) = 34.892, p<.001) in the recall based on the color category; warm colors have more influence as compared to cool and neutral colors (M = 9.0333, SD = 1.90251). Moreover, the cool colors (M = 6.9333, SD = 3.5429) have more influence than neutral colors (M = 4.2000, SD = 1.74988). The

words shown to the participants were of medium size, and a fixation mark was used to maintain the participants' attention.

effect size ($\eta^2=.54$) depicts that color has a strong influence on the recall ability (memory).

Table 2

Mean, standard deviation, and repeated-measure analysis of variance for colored background (N=60).

Variables	Warm color recall 1		Cool color recall 1		Neutral color recall 1		F (2, 58)	η^2
	M	SD	M	SD	M	SD		
Colored background	9.0	1.90	6.93	3.54	4.20	1.75	34.89***	.54

***p<.001

Table 3

Mean, standard deviation, and repeated measure analysis of variance for color-coded.(N=60)

Variables	Warm color recall 1		Cool color recall 1		Neutral color recall 1		F (1,29)	η^2
	M	SD	M	SD	M	SD		
Color-coded	8.43	1.85	5.56	2.85	3.20	1.71	161.69***	.84

***p<.001

Table 3 reveals a significant difference (F (1, 29) = 161.688, p < .001) in recall performance across different color categories. The mean recall scores were highest for warm colors (M = 8.4333, SD = 1.851). Cool colors have more scores than neutral colors and lower scores than warm colors (M = 5.566, SD = 2.8488), and neutral colors have the lowest scores (M = 3.200, SD = 1.710). The effect size is substantial ($\eta^2 = .84$), indicating a strong influence of color on memory recall.

Table 4

Mean, standard deviation, and repeated-measure analysis of variance for colored background.(N=60)

Variables	Warm color recall 2		Cool color recall 2		Neutral color recall 2		F (2,58)	η^2
	M	SD	M	SD	M	SD		
Colored background	9.80	1.97	4.65	1.47	2.93	1.412	285.91***	.98

***p<.001

Table 4 reveals a significant difference ($F(2, 58) = 285.91, p < .001$) in recall performance across different color categories. The mean recall scores were highest for warm colors ($M = 9.8000, SD = 1.9722$). Cool colors have more scores than neutral colors and lower scores than warm colors ($M = 4.6667, SD = 1.47001$), and neutral colors have the lowest scores ($M = 2.9333, SD = 1.412$). The effect size is substantial ($\eta^2 = .98$), indicating an exceptionally strong influence of color on memory recall.

Table 5

Mean, standard deviation, and repeated measure analysis of variance for color-coded.

Variables	Warm color recall 2		Cool color recall 2		Neutral color recall 2		$F(1, 29)$	η^2
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Color-coded	9.30	2.19	5.40	1.33	3.23	1.43	267.12***	.90

*** $p < .001$

Table 5 reveals a significant difference ($F(1, 29) = 267.12, p < .001$) in recall performance across different color categories. The mean recall scores were highest for warm colors ($M = 9.3000, SD = 2.19953$). Cool colors have higher scores than neutral colors and lower scores than warm colors ($M = 5.4000, SD = 1.3287$), and neutral colors have the lowest scores ($M = 3.233, SD = 1.43$). The effect size is substantial ($\eta^2 = .90$), indicating an exceptionally strong influence of color on memory recall reflecting a very strong influence of color on memory recall.

4. Discussion

The current study was completed to investigate the influence of color on memory retention. Furthermore, the study aimed to investigate whether participants may recall more words shown with warm, cool colors (colored background and color-coded words) than those participants exposed to neutral colors. The results indicated that the participants' memory recall is significantly influenced by color, where the recall was highest when the material was presented in warm color as opposed to cool or neutral color. The data consistently demonstrated that cool color (blue) and neutral color (grey) had lower recall rates than warm color (red). Whereas, when doing a comparison between cool and neutral colors, blue has a higher score than neutral colors. The results supported that color perception influences memory retention and participants recall more words shown with warm or cool color (colored background and color-coded words) than those participants exposed to neutral color.

An evident benefit of warm color for memory recall was shown in the investigation. Across both the colored backgrounds and color-coded situations, warm colors had a significantly higher average memory recall than cool colors. This indicates that the warm color irradiation may increase the cognitive processing linked to the recall of memories due to their strong emotional and psychological effects (Purbasari, 2021). The findings are aligned with earlier studies and Elliot and Maier's (2012) study, which demonstrates that warm colors can enhance brain activity by increasing attention and arousal, and pointed out that warm colors like red can be used for better memorization and retrieval of the information.

In addition, both neutral and cool colors have lower recall ratings. Similar to many of the other studies that suggest that while cool and neutral colors do not attract as much attention as warm colors, they also produce less excitement (Class, 2021), warm colors will likely be easier to remember for most people because they contain a higher arousal potential compared to cool colors with their low arousal potential (Spence, 2014). This explains why in our study, warm color was consistently associated with stronger recall.

Prior studies have demonstrated that warm color environments significantly outperform cool color environments and neutral

environments. Therefore, as suggested by Wexner (1954), there are possible benefits for using warm colors in educational or memory-related settings. In addition, a study by Schiller & Smith (2008) stated that warm color environments aid in recalling memories because they decrease the amount of cognitive processing involved with the information presented; therefore, increasing the degree of cognitive involvement.

These results will have a major impact on the development of educational materials as well as educational practices. Purbasari (2021) found that adding warm colors to educational materials could aid in improving student learning efficiency and memory retention; this research is particularly relevant for creating study aids or classroom environments in which increased recall is vital. AL-Ayash et al. (2016) researched whether using warm colored visual stimuli improved academic performance and memory retention; their results also support the use of warm colors in educational environments.

Based on the above discussion, the study concludes that color has an enormous impact on memory retrieval, with warm colors having the largest benefit. These findings provide important insights into how visual cues can be customized to enhance memory performance and cognition.

Limitations

There are, however, some limits to the study since although the study was able to produce positive results, the results were based on a very limited population of 60 participants, so they could not generalize to other populations. The study also focused on particular colors and did not explore the variations among individuals for their preferences and perceptions of color. In future studies, researchers need to examine a wider variety of colors and assess the many ways that humans perceive color.

Recommendations

Prospective studies should, for sure, consider analyzing the impacts of other colors and their combinations, together with the consideration of the role of individual differences in color perception on memory recall. Also, the generalizability of the results would have been enhanced had the sample size increased, and a diverse population been included. All these imply that other factors must be explored, for example, potential pathways to cognition in which color affects memory, the addition of physiological markers, etc.

Ethical Considerations

The consent form was signed by the informants before their inclusion in the study. The participants were assured of their confidentiality and were also told not to disclose the experiment-related information to anyone outside the group. The researcher also reminded the informants that they are free to refuse to participate in the study. In addition, the necessary approval was taken from the institute. The researchers ensured that no participant suffered any harm, nor was any property belonging to the institute damaged.

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