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The Effect of Colored and Grayscale Images on Visual Memory

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ABSTRACT

The purpose of this study is to examine whether colored visuals enhance visual memory performance compared to grayscale visuals. Utilizing a repeated measures design, this experimental study initially involved 39 university students aged between 18 and 25 to account for potential data loss, with 34 participants ultimately included in the final evaluation. As part of the research procedure, a total of 30 visuals (15 colored and 15 grayscale) were presented to the participants in a psychology laboratory computer environment with a specific time limit. Following the visual presentation phase, the "Serial Sevens Test" was administered as a cognitive distractor task to control for factors influencing short-term memory. Subsequently, free-recall forms were provided, and participants were asked to write down the visuals they remembered in any order using one or a few words to evaluate their visual recall performance. According to the experimental results, the recall performance for colored visuals (8.71±2.18) was found to be significantly higher than that for grayscale visuals (6.15±1.94). Thus, the research hypothesis (H1) established as "Visual memory performance for colored visuals is higher compared to grayscale visuals" was supported. The findings of this study are expected to contribute to applications aimed at enhancing information encoding, retrieval, and retention across various fields such as educational material design, advertising and marketing, digital interface design, and digital content production.

Keywords: Visual memory, color effect, memory performance, distinctiveness, recall.

Renkli ve Gri Tonlamalı Görsellerin Görsel Bellek Üzerindeki Etkisi

ÖZ

Bu çalışmanın amacı renkli görsellerin gri tonlamalı görsellere kıyasla görsel bellek performansını artırıp artırmadığını incelemektir. Tekrarlı ölçümler desenine dayalı olarak yürütülen bu deneysel çalışmaya, yaşları 18–25 arasında değişen, veri kaybı ihtimaline karşı 39 üniversite öğrencisi katılmış, 34 katılımcı değerlendirmeye alınmıştır. Araştırma prosedürü kapsamında, katılımcılara psikoloji laboratuvarı bilgisayar ortamında süre sınırlı olacak şekilde 15'i renkli ve 15'i siyah-beyaz olmak üzere toplam 30 görsel sunulmuştur. Görsel sunum aşamasının ardından, kısa süreli belleği etkileyebilecek bilişsel bir dikkat dağıtıcı görev olan "Seri Yedili Testi" uygulanmıştır. Bu görev sonrasında katılımcılara serbest hatırlama formları verilmiş ve hatırladıkları görselleri sırasız olarak bir ya da birkaç kelimeyle yazmaları istenerek görsel geri çağırma performansları değerlendirilmiştir. Deney sonuçlarına göre, renkli görsellerin hatırlanma performansı (8,71±2,18), gri tonlamalı görsellere kıyasla (6,15±1,94) anlamlı düzeyde daha yüksek bulunmuştur. Bu haliyle, "Renkli görseller için görsel bellek performansı, gri tonlamalı görsellere kıyasla daha yüksektir" yönünde kurulan araştırma hipotezini (H1) desteklenmiştir. Çalışma bulgularının, eğitim materyallerinin tasarımında, reklam ve pazarlama, dijital arayüz tasarımı ve dijital içerik üretimi gibi birçok alanda bilgi kodlama, geri çağırma ve akılda kalıcılığını artırmayı amaçlayan uygulamalara katkı sağlaması beklenmektedir.

Anahtar Kelimeler: Görsel bellek, renk etkisi, bellek performansı, ayırt edicilik, hatırlama.

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Introduction

Memory is one of the primary executors of fundamental cognitive processes that enable the encoding, storage, and retrieval of information acquired through experience. Human memory generally consists of multiple interacting subsystems designed to sustain learning and information processing (Baddeley, 2000; Eysenck & Keane, 2015). These subsystems are typically categorized based on their duration and capacity as sensory memory, short-term (working) memory, and long-term memory. Among these systems, episodic memory—a component of explicit long-term memory—plays a central role in the storage and retrieval of personally experienced events and perceptual information (Luria & Vogel, 2011; Hanna & Remington, 1996; Tulving, 1972). Since environmental information is largely acquired through visual perception, visual experiences are encoded and retrieved within episodic memory.

Visual memory is involved in the processes of encoding, maintaining, and subsequently retrieving visual information such as objects, scenes, and spatial relationships. The processing of visual memory depends on a series of perceptual and cognitive factors that influence the encoding of a stimulus. One of the most critical factors affecting memory performance is the distinctiveness of the presented stimuli. Distinctiveness refers to the degree to which a stimulus differs from others within the same context; thus, the stimulus attracts attention and establishes a more robust place during the encoding process. Stimuli with distinctive features are more likely to be effectively encoded and subsequently retrieved from memory (Hunt & Worthen, 2006). Various perceptual attributes, including size differences, unfamiliar shapes, or any contextual variation of a stimulus, play a significant role in distinctiveness. For instance, objects with a larger size relative to their surroundings or those possessing striking contours are more likely to be prioritized by attentional mechanisms. However, among these various distinctive features, color is often identified as the most salient and discriminative perceptual quality. Research indicates that color is processed by the visual system faster and with higher priority than shape or size, providing a powerful "pop-out" effect that guides selective attention (Gegenfurtner& Rieger, 2000). The reason for selecting color as the primary element in this study is its capacity to provide semantic and structural information, which not only contributes to the physical distinctiveness of an object but also enriches its mental representation, thereby contributing to the existence of more permanent memory traces.

Memory performance is also influenced by cognitive processes such as attention and working memory. During the encoding phase, individuals may rely on mental rehearsal strategies to temporarily maintain information. In experimental studies, distractor tasks (e.g., the Serial Sevens Test) are used to interrupt these processes and to ensure that recall is based on long-term episodic memory rather than short-term memory. Distractor tasks impose a high cognitive load on working memory, thereby preventing mental rehearsal (Karzmark, 2000), and information rapidly decays in short-term memory (Peterson ve Peterson, 1959).

The processes that determine memory performance are not limited to cognitive-level mechanisms but also include perceptual features that influence the way information is encoded. Color is considered one of the most distinctive perceptual features among visual stimuli. In everyday perception, color plays an important role in the naming, categorization, and interpretation of objects and scenes (Lannetti & Allred, 2013). This prominent role of color in perceptual processes suggests that it may influence not only immediate perception but also how information is encoded in memory. Therefore, understanding how visual stimuli are transformed into memory representations becomes an important requirement for explaining the effect of color. Various theoretical frameworks (e.g., Schema Theory, Information Processing Model, and Dual Coding Theory) have been proposed to explain the effects of color on memory. Among these theories, Dual Coding Theory proposed by Paivio (1971/1991) provides a more comprehensive framework for explaining the impact of color on memory performance.

Paivio (1971/1991) proposed the Dual Coding Theory, which holds that information is processed by two distinct but related systems: a verbal system and a visual-spatial (imagery). According to this theory, color is processed together with visual stimuli, leading to a stronger activation of the imagery system. By providing an additional encoding cue, it contributes to the formation of “dual-coded” representations and thereby enhances the strength and durability of memory traces. Empirical studies (e.g., Gegenfurtner& Rieger, 2000; Wichmann et al., 2002; Spence et al., 2006) also support the positive effects of color on memory.

At this point, the literature review demonstrates that perceptual features such as color provide both a theoretical and empirical basis for understanding their potential effects on memory processes. However, a considerable portion of existing research has focused on the effects of color on general perception and recognition processes, while the role of color in more controlled experimental settings—particularly those involving a distractor task to ensure that recall relies primarily on episodic memory—has been relatively underexplored. Therefore, examining the distinctive contribution of color to visual memory performance in a more controlled experimental context is important for extending the current findings in literature. The present study aims to compare the effects of color and grayscale images on visual memory performance and to experimentally evaluate the functional role of color in the encoding process.

The aim of the study

The aim of this study is to investigate whether color images improve visual memory performance compared to grayscale images. Study hypotheses are formulated as follows:

H_1: Color images lead to higher visual memory performance compared to grayscale images.

H_0: There is no significant difference in visual memory performance between color images and grayscale images.

The significance of the study

Investigating the effects of colored and grayscale images on memory is important for understanding attention and encoding processes, as well as for identifying the visual cues that influence memory performance. The findings of this study are expected to contribute to applications aimed at improving information retention in the design of educational materials (e.g., the use of visuals in textbooks), in advertising and marketing (e.g., visual color strategies in product presentations), in digital interface design (e.g., the arrangement of visual elements in application and web designs), and in digital content production (e.g., social media visuals and video content).

Method

Research Design

This research was designed as an experimental study to examine the effect of color and grayscale visuals on visual memory performance. The independent variable in the study was the type of visual image (color and grayscale), and the dependent variable was visual memory recall performance. A within-subjects design was used in the research. In a within-subjects design, each participant is exposed to all experimental conditions, allowing for comparisons between the same individuals. In this experiment, all participants were exposed to both color and grayscale visual conditions. The study aimed to control differences between participants and to examine the effect of visual characteristics on memory performance more directly.

Ethics of the Study

Ethical approval for this research was obtained from the Istanbul 29 Mayis University Non-Interventional Clinical Research Ethics Committee with decision number 2026/03-5 dated 02.03.2026. The research was conducted in accordance with ethical principles, and voluntary consent was obtained from the participants. The personal data of the participants were kept confidential and used only for scientific purposes.

Participants

The sample consisted of 34 university students between the ages of 18 and 25. The required sample size was determined through a priori power analysis conducted using G*Power (v3.1.9.7). Based on commonly accepted medium effect size in the literature (Cohen, 1988; d = 0.50), an alpha level of .05, and statistical power (1 − β) of .80 for a within-subjects design, the minimum required sample size was calculated to be 34 participants. To account for possible data loss or incomplete participation, five additional participants were recruited, resulting in a total of 39 recruited participants. The study protocol specified that only the first 34 participants who completed the experimental procedure would be included in the final analyses. Since all participants required for the planned sample size provided complete and valid data, the final analyses were conducted with 34 participants.

Inclusion and exclusion criteria were established while forming the study sample. Undergraduate and graduate university students aged 18–25 years, with no neurological disorders and with normal or corrected-to-normal vision, were included in the study. Participants who reported color blindness or clinically significant visual impairments were excluded. In addition, forms containing incomplete data were not included in the analysis. Participants' mean age was 21.47 years (SD = 2.13; range = 18–25). Demographic characteristics of the participants are given in Table 1.

Table 1. Demographical Characteristics

Variables	Labels	n	%
Sex	Female	20	58.8 %
	Male	14	41.2 %
Age Groups	18-20 Years	9	26.5 %
	21-25 Years	25	73.5 %
Education Status	Undergraduate	27	79.4 %
	Graduate	7	20.6 %
N		34	100 %

Data Collection Tools

In this study, a Sociodemographic Information Form (SIF), a Visual Stimulus Set, and the Serial Sevens Test and Recall Response Form were used to collect data. Information regarding participants' age, sex, and educational status was obtained through the SIF.

Visual Stimulus Set consisted of a total of 30 images, 15 in color and 15 in grayscale, and was presented to participants on a computer within a time limit (See Figure 1). Color and grayscale stimuli were not created as different versions of the same visual content; different visuals were used for each condition. However, to ensure that the stimuli had as similar features as possible in terms of content, the visuals were selected from the same semantic categories. A grayscale method was used to transform the images, preserving luminance information. All stimuli were presented at the same size and displayed in a fixed position on the screen during the experiment.

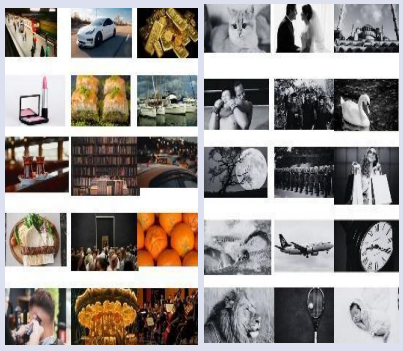

Figure 1. Visual Stimulus Set

The Serial Sevens Test was administered to create a cognitive distracting effect. This task is an attention and calculation task implemented to prevent active rehearsal in working memory and to measure recall from long-term memory (Hayman, 1942). In this task, participants were asked to repeatedly subtract seven from the number 1000 and write down their results within 60 seconds (See Table 2). This task is widely used in experimental and clinical research to impose cognitive load on working memory and disrupt rehearsal processes (Hayman, 1942; Karzmark, 2000).

Table 2. Serial Sevens Test

1000	[.993.] ->[.986.] ->[.....] ->[.....] ->[.....] ->[.....] ->[.....] ->[.....] ->[.....] ->[.....] -> ...

Recall Response Form was used to record participants' memory responses during the recall phase of the experiment (See Table 3). Participants' visual memory recall performance was evaluated after the Serial Sevens Test.

Table 3. Recall Response Form

No	Recalled Image / Detail Description	Score (Researcher's Note)
1	White Car, Tesla	+1 Colored
2	Cat	+1 (Greyscale)

Procedure

This experimental study was conducted in a psychology research laboratory to provide a controlled environment. Participants were admitted to the laboratory individually and, before the experimental procedure began, were informed about the general purpose of the research and asked to sign an informed consent form. Subsequently, the sequence of tasks to be performed during the experiment was explained to the participants. The implementation process was then initiated, and the experiment was conducted by the same researcher throughout all stages. Experimental procedure consisted of three sequential phases: encoding phase, distractor task, and recall test phase.

In the first phase (encoding), a total of 30 visual stimuli were presented, consisting of 15 color images and 15 grayscale images. Visual stimuli were presented centrally on a 15-inch monitor. Each participant viewed the stimuli from approximately 60 cm away from their own monitor. Each image was displayed on a computer screen for three seconds. A 500-millisecond interstimulus interval with a blank screen was presented between stimuli to reduce perceptual overlap (See Figure 2). Participants were instructed to carefully examine the images and then undergo a recall test. The same set of 30 visual stimuli was presented to all participants. The stimulus set consisted of 15 colored images and 15 grayscale images, and the same presentation order was used for all participants. Therefore, potential order effects arising from differences in stimulus presentation sequence across participants were controlled. The presentation order of the images was determined prior to the experiment and remained constant for all participants.

The 30 stimuli were presented in a predetermined pseudo-random order, with colored and grayscale images intermixed. Using the same presentation sequence for all participants ensured standardization of the experimental procedure. Potential variability due to differences in stimulus presentation order across participants was minimized.

Figure 2. Display sequence of visuals

In the second phase (distractor task), The Serial Sevens Test was employed. Participants were asked to repeatedly subtract seven from the number 1000 and write down the resulting numbers in sixty seconds. This procedure was implemented to prevent participants from rehearsing the previously presented visual stimuli and to ensure that subsequent recall performance reflected long-term memory processes rather than short-term memory processes (Peterson & Peterson, 1959).

Instruction: "Now I will ask you to perform a mathematical operation. Starting from the number 1000, please subtract 7 from each resulting number and write the results in the boxes below in order. Try to proceed as quickly and accurately as possible."

In the last phase (recall test), participants were asked to recall the images presented to them. Here, participants were instructed to write down all the images they could remember. During the recall phase, participants were given five minutes to list the images. Starting from the encoding phase, participants were asked to describe the images they recalled in any order, and each correctly recalled image was counted as one point. Scores for colored and grayscale images are reported separately.

Instruction: "Please list every object or scene you remember from the photographs you just saw on the screen, in any order, in the spaces provided below. Please write each distinct item on a new line."

To minimize subjectivity in scoring and to maintain internal validity, the data were coded by two independent raters. Recall responses were evaluated according to a predefined correct answer scheme, and separate recall scores were calculated for colored and grayscale images. Agreement on scoring between two evaluators was assessed using Cohen's coefficient, and

differing responses were resolved through joint evaluation.

Data Analysis

Statistical analyses were conducted using IBM SPSS Statistics 23.0. Parametric tests were used in the analyses due to the sufficient sample size (n>15) and the robustness of parametric tests against the normality assumption. Before conducting the analyses, assumption checks were performed. In dependent sample comparisons, the normality assumption was examined using skewness and kurtosis values. The significance level was accepted as α = .05 in all statistical analyses. A paired samples and independent samples t-tests were used for the comparison analyses.

Results

In this section, comparative analysis (Paired Samples T-test and Independent Sample T-test) analysis results will be presented, respectively.

Comparative Analysis

A paired samples t-test was used to evaluate the difference in recall performance between participants for colored and grayscale (black-and-white) images. The results show a statistically significant difference in participants' recollection performance, t(33)=4.61, p<.001. Colored images (M= 8.71, SD= 2.18) are recalled more than grayscale images (M= 6.15, SD=1.94). (See Table 4).

Table 4. Paired Sample Sample T-test

	Colored images		Grayscale images		*t (33)*	Cohen's d_av	p
Recall Performance	X̄	Sd	X̄	Sd	4.619	1.24	.000*
	8.71	2.18	6.15	1.94			

*p<.001

An independent sample t-test was conducted to examine whether there were differences in recall performance based on sex. The analysis results are presented in Table 5. The results indicated that no statistically significant difference was found between sexes in the recollection of colored and grayscale images, t(32)=-0,17, p> .05; t(32)=0.90, p>.05.

Table 5. Independent Sample T-test

	Female		Male		*t (32)*	p
	X̄	Sd	X̄	Sd		
Colored Images	8.65	2.15	8.79	2.29	-0.17	.861*
Grayscale mages	6.40	1.75	5.79	2.19	0.90	.372*

Discussion and Conclusion

The aim of this study was to investigate whether color images improve visual memory performance compared to grayscale images. The study hypothesis was formulated as follows: color images lead to higher visual memory performance than grayscale images. The obtained findings indicated that colored visuals were encoded and retrieved better than grayscale visuals. Thus, hypothesis (H1) was supported.

The study yielded findings similar to those reported in previous literature regarding the effects of color on memory performance. For instance, Wichmann, Sharpe, and Gegenfurtner (2002) reported that participants' recognition performance was 5–10% higher for colored images than for black-and-white images, irrespective exposure duration. Dzulkifli and Mustafar (2013) found that color plays an important role in the successful encoding, storage, and retrieval processes of environmental stimuli, and that the choice and manipulation of colors substantially and positively influence the recall function in memory. In a similar vein, in the experimental study conducted by Huchendorf and Cary (2007), 115 university students were given a list of 20 words presented in different colored and grayscale packages, after which their attention was distracted by a mathematical task, and their recall scores were measured. In this word and object recall experiment, which bears a high similarity to the present research, it was observed that participants exposed to colored stimuli demonstrated higher recall success compared to those exposed to grayscale stimuli. In a recent study examining color and visual memory, Liang (2025) investigated the effect of color coding in 3D game scenes on participants' episodic memory; through interviews and surveys, it was reported that color coding significantly enhanced players' episodic memory compared to grayscale variations, enabling them to display better performance. Furthermore, Cornelissen and Greenlee (2000) demonstrated through an experimental design that contrast and color information have a more distinctive function in visual short-term memory than grayscale stimuli. Finally, Isola et al. (2011) initiated their research based on the premise that individuals are constantly exposed to photographs in environments such as magazines and the internet but do not remember them all equally; they concluded that one of the most significant factors in visual memorability is the presence of color information and its impact on visual salience. Considering these outcomes, it has been verified that the findings obtained in this research exhibit consistency with numerous studies in literature.

However, the effect of color on memory is not uniform across all memory tasks. Previous studies have shown that color knowledge provides more significant advantages, particularly in recognition memory tasks, while in free recall tasks, this effect may be more limited or dependent on the characteristics of the task (Wichmann et al., 2002). This suggests that color may function as a cue, particularly facilitating the

discrimination and recognition of previously encountered stimuli. Therefore, it is important to evaluate the current findings within the context of free recall tasks.

These findings support Paivio's (1971/1991) Dual Coding Theory, which posits that information is processed through two distinct systems: verbal and imagery. In this framework, color information serves as an additional cue within the imagery system, facilitating a more robust consolidation of information (Zimmer et al., 2002). Results support the premise that color is a crucial factor in strengthening the mental representation of information. Furthermore, the study confirms that color, by contributing to perceptual salience and distinctiveness, positively influences the encoding and retrieval processes of stimuli within episodic memory (Wichmann et al., 2002; Spence et al., 2006). In line with this, the results align with the findings of Spence et al. (2006), which indicated that the presence of color in natural scenes leads to more permanent and powerful traces in recognition memory compared to grayscale versions of the same images. This research also supports the findings of Gegenfurtner and Rieger (2000), who observed that color information facilitates the recognition of stimuli, scenes, and objects by providing additional perceptual and semantic cues that support cognitive processing. The significantly higher recall of colored images over grayscale ones underscores the cognitive importance of chromatic information in visual processing.

Furthermore, the contribution of color to memory may also depend on the degree to which the presented objects have distinctive color information. In objects with high color diagnosticity, color can support encoding by providing additional semantic information about the object's identity, while in objects with low color diagnosticity, this contribution may be more limited (Spence et al., 2006). Therefore, the magnitude of the color effect can vary depending on the characteristics of the stimuli used.

However, the current findings should not be explained solely by the cognitive effects of color. In this study, different visuals were used instead of different versions of the same images under color and grayscale conditions. Although the stimuli were selected from the same semantic categories to minimize content differences, it is possible that some features specific to the visuals also contributed to recall performance. Therefore, the current design does not allow for a complete separation of the effect of color knowledge from visual features.

Regarding the potential influence of sex differences, the results of the independent samples t-test showed no significant variation between sexes for either image type. This suggests that the enhanced encoding and recall associated with color is related to universal visual memory processing mechanisms rather than sex-dependent factors. This finding contributes to the literature by demonstrating that the effect of color on memory remains consistent across demographic differences.

This finding may indicate that participants directed their attention resources to a specific visual feature rather than general memory capacity. Specifically, the higher perceptual clarity of the color stimuli may have led to a prioritized attentional shift towards the encoding of color images in some participants. However, this relationship should be interpreted with caution due to the small sample size.

In conclusion, this study demonstrates that colored stimuli are associated with higher recall performance compared to grayscale stimuli. However, it should be considered that this relationship may be influenced by task characteristics, the structure of the stimuli, and the experimental design used. Accordingly, the present findings should not be interpreted as evidence that color universally enhances memory performance. Rather, they indicate that colored stimuli were associated with better recall under the specific experimental conditions employed in this study.

Limitations: Despite achieving its primary objectives, this research is subject to several limitations that should be considered when interpreting the findings:

Sample Composition and Size: The study was conducted with a sample of 34 undergraduate students. This specific composition limits the generalizability of the results to populations with different age ranges or educational backgrounds. However, since cognitive processes in young adults (ages 18–25) exhibit distinct developmental characteristics compared to children and the elderly, this group provides strong representational power for this specific life stage.

Laboratory Setting: The experiment was conducted in a controlled laboratory environment where all distracting variables were held constantly. The isolated presentations in the laboratory differ significantly from real-world exposure to visual stimuli, such as billboards, environmental noise, and social interactions. Consequently, this may limit the ecological validity of the study.

Nature of Visual Stimuli: The images used were categorized to be easily described with a few words, ensuring they did not impose excessive perceptual or cognitive loads on the participants. Important factors that could influence memory performance -such as the emotional valence (positive, negative, or neutral), the level of complexity (simple objects vs. crowded scenes), and the concreteness or abstractness of the images (Liang, 2025)- were not analyzed in depth. Although maintaining a fixed stimulus presentation order ensured procedural consistency, the inability to separate condition effects from order effects should be acknowledged as a limitation of the study.

Visual Stimulus Selection: A significant limitation of this study is that the color and grayscale stimuli were not presented as two different versions of the same image. Instead, different visuals selected from the same semantic categories were used for each condition, and

all participants were shown the same set of stimuli in the same presentation order. While this design allowed for standardization of the experimental application, it did not allow for a complete separation of the effects of the color condition and visual-specific features (e.g., recognizability, semantic clarity, or inherent memorability). Therefore, the resulting recall advantage may be partly dependent not only on color knowledge but also on some stimulus-specific features.

Temporal Constraints: Although a distractor task was utilized to mitigate short-term memory effects, the recall test was administered immediately after the 60-second task. The lack of assessment for long-term retention (e.g., after 24 hours) or memory permanence (e.g., follow-up tests weeks later) prevents the observation of the long-term effects of color on memory traces.

Suggestions: The following suggestions are proposed for future research, building upon the findings of this study:

Expanded Sample Diversity: Future studies could be conducted with more heterogeneous sample groups including different ages and educational levels. This would allow for the observation of how color-related memory performance changes according to developmental differences.

Diverse Color Palettes and Stimuli Types: While this study focused on the binary distinction between colored and grayscale images, future research could investigate the specific effects of warm (red, orange) versus cool (blue, green) color palettes. Furthermore, the impact of more abstract and complex imagery on encoding and recall performance could be measured. In future studies, preferring experimental designs that use both color and grayscale versions of the same visuals and assign these versions counterbalanced among participants will contribute to a more precise assessment of the specific effect of color on memory.

Delayed Recall Assessments: To gain a deeper understanding of memory functioning beyond immediate recall, future research could implement free recall tests at intervals of one hour, one day, or one week. This would provide a more comprehensive view of the impact of color on long-term memory systems.

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