

Seeing Isn't Believing: How Visual Illusions Distort Color Selection

SARI KOBAYASHI, SATOSHI NAKAMURA, Meiji University, Japan

Color selection interfaces, such as color palettes and pickers, are essential tools in digital design software. However, these interfaces can unintentionally introduce visual illusions, particularly when the surrounding area alters the perceived appearance of the selected color. This study investigates how such illusions, especially brightness effects, distort color perception and lead to mismatches between selected and applied colors. Through two experiments, we make four key contributions. First, we empirically demonstrate that brightness illusions systematically bias color selection depending on the luminance of the surrounding area. Second, we show that decreasing the display size of the selected color increases perceptual inaccuracies, highlighting the importance of visual emphasis in interface layout. Third, we examine the influence of chromatic backgrounds and identify specific hues and framing conditions that minimize inaccuracy. Finally, based on these findings, we offer practical design implications for improving the accuracy and intuitiveness of color selection interfaces. Our results underscore the need to account for perceptual mechanisms when designing tools that support precise visual tasks.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**.

Additional Key Words and Phrases: Color selection, color palette, color picker, background color, optical illusion

ACM Reference Format:

Sari Kobayashi, Satoshi Nakamura. 2025. Seeing Isn't Believing: How Visual Illusions Distort Color Selection. In *Proceedings of Generative Intelligences, Planetary Futures 37th Australian Conference on Human-Computer Interaction (OzCHI 2025)*. ACM, New York, NY, USA, 21 pages. <https://doi.org/10.1145/nnnnnnn.nnnnnnn>

1 Introduction

Color is a critical element in design, and many users are particular about selecting the right color [40]. To support this process, various color selection interfaces such as color pickers and color palettes are commonly used. However, users often spend considerable time finding their desired color, partly because the selected color may appear different when applied to the canvas [23, 44]. This discrepancy can reduce design efficiency and result in unintended visual outcomes, especially in tasks that require precise color coordination. One possible cause of this mismatch is the influence of visual illusions introduced by the color selection interface itself.

Color selection interfaces are not just technical tools but also perceptual environments. The way colors are presented within these interfaces can subtly alter users' perception, leading them to make unintended choices. These illusions are particularly problematic in professional design workflows, where visual consistency and precise color communication are essential. Despite their practical significance, such perceptual distortions remain underexplored in interface research.

For example, in the color picker of PowerPoint(Windows), the interface features a white background and displays the selected color within a preview box outlined in red. As a result, the previewed color often appears darker than it

Author's Contact Information: Sari Kobayashi, Satoshi Nakamura, Meiji University, Japan.

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actually is. This phenomenon is likely related to a brightness illusion, in which the perceived brightness of a color is influenced by the brightness of its surrounding area [42].

Another factor that complicates color selection is the use of gradient-based interfaces. For instance, paint software often uses a gradient color picker where hue, brightness, and saturation are displayed as a continuous surface. While these interfaces are useful for visualizing a broad range of color variations, they can make it difficult to perceive subtle inaccuracies when adjusting the cursor. This issue is related to a visual phenomenon known as color assimilation, in which a color appears more similar to its surrounding colors than it actually is [18]. For example, A gray area with identical brightness is shown on both black and white backgrounds; the background color causes the perceived color of the gray region to shift.

These examples highlight how visual illusions can cause a mismatch between the intended color and the color as it appears in the final design, potentially altering the overall impression. Moreover, such mismatches may require users to make additional adjustments, increasing the overall workload of the design process. These problems are not limited to expert users. Novice users may be particularly vulnerable to such illusions, as they rely more heavily on preview displays to assess visual outcomes. Therefore, designing color selection interfaces that account for visual illusions is essential to support accurate and intuitive color choices across diverse user groups.

This study aims to identify the perceptual mechanisms behind such mismatches and to examine how they arise under different interface conditions. As a first line of investigation, we focus on brightness illusions that occur within color selection interfaces. The selected color is presented within a visual context defined by the interface's background color, which can alter how the color is perceived. As a foundational step toward interfaces that mitigate perceptual distortions, we aim to clarify how brightness illusions emerge when selected colors are displayed against various background colors.

As a second line of investigation, we explore the impact of the size of the color display. In most color selection interfaces, the selected color is shown in a limited area that shares space with other candidate colors and interface elements. We hypothesize that a smaller display area may hinder users from accurately perceiving the selected color. Additionally, while most interfaces use achromatic (i.e., grayscale) backgrounds, little is known about how chromatic backgrounds affect users' color selection behavior. To test the hypothesis, we investigate how users' color choices are influenced when the selected color is surrounded by chromatic backgrounds of varying sizes. We hypothesize that both the hue of the surrounding area and the display size of the selected color affect perceptual accuracy. Our goal is to identify how these factors contribute to selection inaccuracies in color interfaces.

The contributions of this study are as follows:

- We empirically demonstrate that brightness illusions occur in color selection interfaces, causing systematic mismatches between selected and perceived colors depending on background luminance.
- We show that the relative size of the color display influences perceptual accuracy, with larger display areas reducing inaccuracy in color matching tasks.
- We investigate how chromatic surrounding areas influence color selection and identify specific hues and surrounding area sizes that increase perceptual inaccuracy.
- We provide design implications for developing color selection interfaces that mitigate visual illusions, supporting more accurate and intuitive color choice behavior.

2 Related Work

2.1 Visual Illusions in Color Perception and Color Selection Interfaces

Color illusions have been shown to occur independently of specific patterns or coloration types, leading to variations in visual impressions and perception [4, 16, 25, 28, 29, 35]. To mitigate such illusions, several studies have proposed methods involving object manipulation or color correction techniques, with their effectiveness empirically demonstrated [2, 14, 31]. In addition, models have been developed to predict brightness illusions as well as perceived color in photographs, suggesting their potential applicability to color pickers that account for user perception [21, 27]. However, many of these approaches focus on specific visual patterns or post-processing of completed images, rather than addressing issues within the color selection interfaces used during the design process. Therefore, it is essential to improve color selection interfaces themselves as a means of preventing perceptual mismatches during active design work. Recent research has extended this line of inquiry by examining how illusions are affected when combined with chromatic stimuli. Building upon this direction, the present study investigates how colors are perceived within color selection interfaces and explores how visual illusions can be addressed through interface design.

While these studies primarily address perceptual distortions themselves, another line of work has focused on developing tools to assist users in selecting aesthetically pleasing or harmonized colors.

2.2 Studies on Supporting Color Selection

A variety of systems have been developed to assist users in selecting colors, typically by recommending appropriate color combinations. For example, services such as Colormind, ColorHunt, Adobe Color, and Paletton offer predefined color palettes [3, 9, 12, 33]. These tools often support user interaction, including adjusting color tones or regenerating palettes while preserving specific colors. Guosheng et al. [22] proposed a color scheme support tool based on color harmony theory. Their findings suggest that the tool is useful both for design novices who prefer predefined combinations and for professionals who want to validate color harmony in their designs. Tamaki et al. [41] developed a system that generates palettes based on textual cues from layer names, enabling users to select colors that align with conceptual imagery. Their results indicate that this method supports user creativity more effectively than traditional palette-based approaches. Beyond random palette generation, several studies have explored techniques for extracting colors from images. Delon et al. [10] implemented a hierarchical algorithm for generating representative palettes from arbitrary images, with emphasis on hue and saturation. Shi et al. proposed a palette that reflects the spatial arrangement of colors and their relative areas within an image. They demonstrated that this approach enables more flexible recoloring compared to existing palettes [38]. Taehong et al. [24] proposed a method using hierarchical clustering to extract color models without dependence on spatial regions, enabling interactive merging and splitting of color regions. Karim et al. [26] further extended this model with a node-link interface for color exploration, demonstrating improved efficiency and flexibility in five-color palette generation. Such image-based palette generation has also been used to associate palettes with user-defined keywords. Xu et al. [46] demonstrated the effectiveness of crawling web images based on given keywords and extracting relevant color palettes to assist users in finding desirable color impressions.

While these systems support color selection by presenting predefined candidate colors, actual design tasks often require users to make fine-grained, individual selections. Therefore, the present study focuses on supporting user-driven color selection beyond preset palettes. In parallel with palette recommendation systems, researchers have also investigated how the design of the color selection interface itself influences usability and user behavior. In addition,

various methods for presenting suggested colors have been proposed. However, it remains unclear which presentation methods are most effective in supporting intuitive and accurate color selection.

2.3 Studies on Color Selection Interfaces

In addition to palette generation, the usability of color selection interfaces themselves has been a subject of research. Prior work has identified challenges in interface design, including the choice of color spaces and feedback mechanisms for selected colors [19, 36]. Studies have shown that the method of displaying colors within pickers affects user behavior, task completion time, and satisfaction [5–7, 45, 47]. Design processes often involve stages such as reference collection, color planning, and prototyping [17, 40], in which color selection plays a central role. For novice users, especially those unfamiliar with screen-to-print discrepancies, supportive interfaces can foster creativity. To address this, Henry et al. [20] proposed an interface that promotes learning through use. It has also been noted that users prefer conducting all design stages on a single screen [17], emphasizing the need for both speed and accuracy. The Color Portraits study [23], based on designer interviews, highlighted the influence of surrounding elements and the need for interfaces that support the exploration of inter-color relationships. Similarly, the Interactive Palette Tool [30] enabled users to experiment with color combinations drawn from reference images, helping them overcome perceptual uncertainty. Some researchers have proposed limiting the color options to improve usability. Moens et al. [32] restricted the number of visible colors to enlarge each display area, thereby enhancing intuitive selection. Their interface used 11 basic color categories to support color-based search. Gramazio et al. [15] introduced Colorgorical, which allows users to adjust hue ranges and prioritize perceptual discriminability. Comparative evaluations confirmed its effectiveness in satisfying user preferences. Contrast-aware methods have also been explored. Sandnes et al. [37] proposed a recommendation system that suggests colors compliant with contrast guidelines. For data visualization, Wijffelaars et al. [43] developed a model that displays only colors satisfying certain constraints, achieving expert-level palette quality. Other systems support dynamic blending and manipulation of colors. Playful Palette and Color Builder provide interactive tools for mixing and visualizing color transitions [39, 40]. These tools were found to promote creativity and exploration. BiCEP [13] and ColorFingers [11] offer multitouch color pickers that enable simultaneous adjustment of hue, saturation, and brightness. These systems significantly improved both speed and accuracy over traditional models.

Together, these studies demonstrate the potential of color selection interfaces that support intuitive and rapid interactions. However, in contrast to these efforts, the present research highlights the risk that perceptual illusions embedded in interface design may interfere with accurate and intuitive color selection, suggesting a need for interface design that explicitly accounts for such perceptual distortions.

3 Experiment 1: Effect of Achromatic Background Brightness on Color Selection

3.1 Method

In the context of color selection interfaces, brightness illusion refers to the phenomenon in which the perceived brightness of a color changes depending on the brightness of the area surrounding it. This suggests that if the background of the color picker differs from that of the canvas, a brightness illusion may occur during the color selection process. Specifically, a color surrounded by a bright area may appear darker than it actually is, leading users to select a color that is brighter than intended. Conversely, a color surrounded by a dark area may be perceived as brighter, prompting users to select a color that is darker than intended. However, the extent to which users are affected by such illusions when using a color picker has not been thoroughly investigated. To address the issue of perceptual mismatch in color

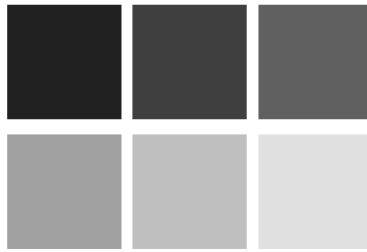


Fig. 1. Brightness Levels Presented in Each Condition (Arranged from Top Left: 13, 25, 38, 63, 75, 88).

selection interfaces, this study examines the influence of brightness illusions on color selection behavior. We analyze the relationship between the selected color and the target color to identify patterns of inaccuracy induced by surrounding brightness.

To test the hypothesis that a mismatch between the surrounding brightness of the target and selected color induces brightness illusions, we designed a task in which participants were asked to match an achromatic target color displayed on one background to a color selected using a color picker shown on a different surrounding area. Participants adjusted the brightness of the selected color until it visually matched the target, while observing how it appeared against the specified background. Because hue, saturation, and brightness all interact to affect color perception, and can introduce complexity, we limited the experiment to grayscale colors that vary only in brightness. Colors were represented using the HSV color model, with brightness values ranging from 0 to 100.

The experiment included six surrounding brightness conditions: 13, 25, 38, 63, 75, and 88. These values were derived by dividing the full brightness range (0–100) into eight intervals and excluding 0, 50, and 100 based on findings from a pilot study. In that study, values of 0 and 100 made color matching particularly difficult by perceptual limitations, while 50 was excluded because it matched the default background brightness of the experimental interface. These brightness levels are illustrated in Figure 1.

The experimental interface, developed using Processing, is shown in Figure 2. The top of the screen displayed the target color, while the lower left area showed the selected color against the specified background. A slider-style color picker was located on the lower right. In each trial, a new target color was randomly generated, and the background color was fixed for the duration of that condition. Participants were instructed to adjust the slider to match the target color.

Participants were instructed to move the color picker using mouse clicks and to make fine adjustments in brightness by one unit using increment/decrement buttons placed beside the picker. When participants judged that the two colors matched, they proceeded to the next trial by clicking the “Next” button displayed at the top right of the screen. To minimize any carryover effects from the previous trial’s selection, the default value of the selected color was reset to brightness value (100) at the beginning of each new trial. Each participant completed 30 trials per brightness condition. To prevent abrupt perceptual shifts due to large changes in brightness across trials, all participants completed the six conditions in a fixed order: 13, 25, 38, 63, 75, and 88. Participants completed all trials in a single session, with a short break of 30 to 60 seconds provided after every 100 trials to reduce fatigue. The experiment was conducted in a well-lit indoor environment. Participants were seated directly in front of a computer monitor with standardized display brightness and maintained a consistent viewing distance of approximately 50 cm throughout the session. A total of

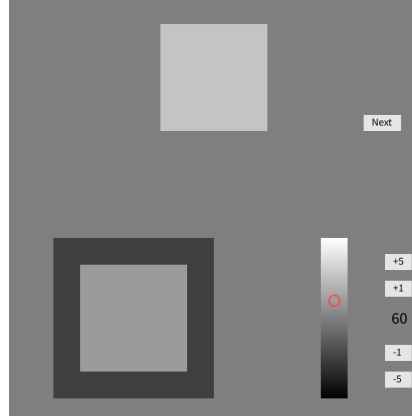


Fig. 2. The experimental interface displayed the target color at the top of the screen. The color selected using the color picker, located at the bottom right, was shown at the bottom left, surrounded by a specified color. The system background color is set to brightness 50.

20 participants (12 male, 8 female) took part in the study. The participants were not professional designers, but they routinely engaged in design-related activities, such as preparing presentation materials.

3.2 Results

Figure 3 shows the inaccuracies between the target brightness values (hereafter, target values) and the brightness values of the colors selected by participants (hereafter, selected values) under each surrounding brightness condition. Positive values indicate that the selected color was brighter than the target, and negative values indicate that the selected color was darker than the target. From the Figure 3, it is evident that under the surrounding brightness conditions of 13, 25, and 38, the selected values tended to be lower than the target values, indicating that participants chose colors darker than the targets. Conversely, under the brightness conditions of 75 and 88, the selected values tended to be higher than the target values, indicating a tendency to choose brighter colors.

Table 1 shows the absolute inaccuracies between selected and target values across all conditions. Among these, brightness 63 yielded the smallest average inaccuracy. Analyzing inaccuracy by target brightness range within each condition revealed the following:

- For brightness 13, the lowest inaccuracy (2.74) was in the 90–100 range, and the highest (6.55) in the 10–19 range.
- For brightness 25, the lowest (2.63) was in 50–59, and the highest (5.63) in 20–29.
- For brightness 38, the lowest (3.24) was in 50–59, and the highest (5.98) in 70–79.
- For brightness 63, the lowest (1.94) was in 30–39, and the highest (5.02) in 0–9.
- For brightness 75, the lowest (2.02) was in 30–39, and the highest (6.17) in 0–9.
- For brightness 88, the lowest (2.69) was in 80–89, and the highest (7.23) in 0–9.

When comparing across conditions for each target range, the background that produced the smallest inaccuracy was:

- Brightness 25 for target brightness range 0–9
- Brightness 63 for target brightness range 10–49
- Brightness 75 for target brightness range 50–79

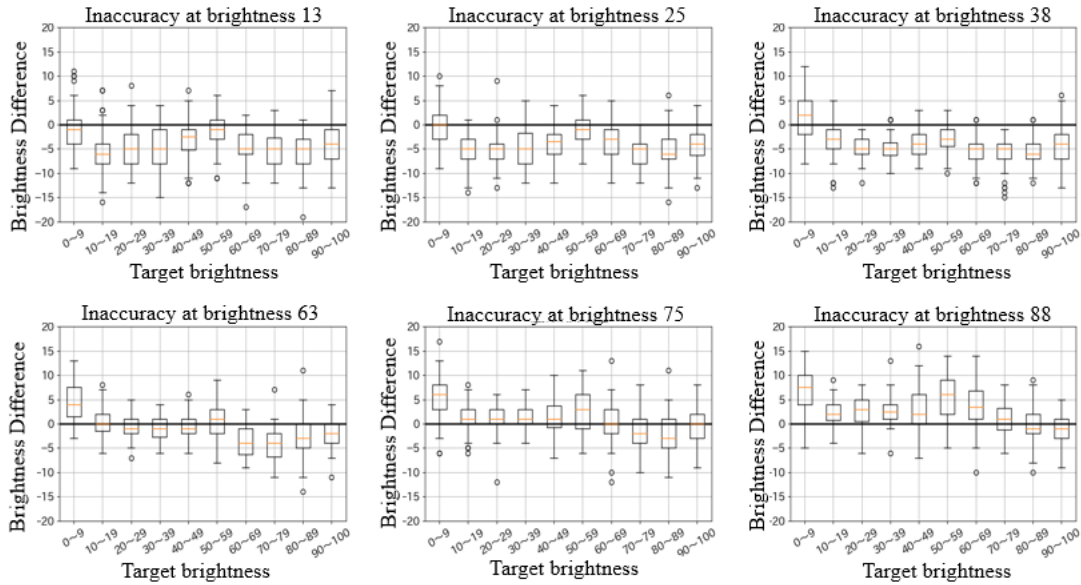


Fig. 3. Inaccuracy between target and selected values in each condition. The x-axis indicates the ranges in which the target values fall, while the y-axis represents the distribution of the inaccuracies between selected and target values across all 20 participants. If the y-axis value is greater than 0, it indicates that the selected color was lighter than the target color; if the y-axis value is less than 0, it indicates that the selected color was darker than the target color.

Table 1. Average absolute inaccuracies in brightness between the target color and the selected color.

	Average inaccuracy
Brightness 13	4.81
Brightness 25	4.57
Brightness 38	4.70
Brightness 63	3.09
Brightness 75	3.21
Brightness 88	4.00

- Brightness 88 for target brightness range 80–89
- Brightness 75 again for target brightness range 90–100

Figure 4 visualizes the absolute inaccuracies in each condition as a bar graph. In the target ranges 10–49 and 60–100, background brightness conditions below 38 led to larger inaccuracies. In contrast, for the 50–59 range, higher brightness conditions (above 75) resulted in greater inaccuracies. Notably, in low-brightness background conditions, the closer the target was to medium brightness, the smaller the inaccuracy. In high-brightness conditions, the opposite trend was observed: the closer the target was to medium brightness, the larger the inaccuracy. These findings suggest that dark backgrounds reduce inaccuracy for medium-brightness targets, while bright backgrounds reduce inaccuracy for very dark or very bright targets.

Table 2 summarizes the number of participants for whom each condition resulted in the smallest inaccuracy, along with the corresponding average inaccuracy for those participants. While brightness 63 was the condition with the most

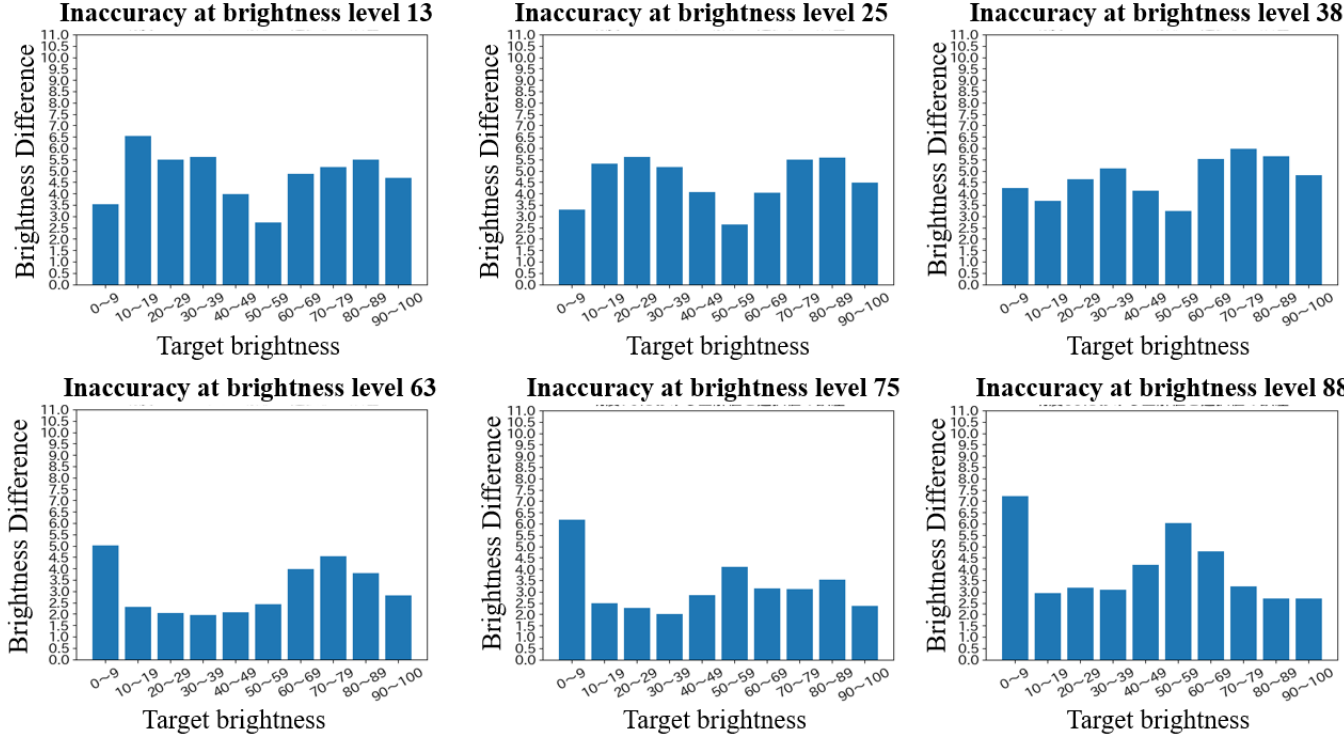


Fig. 4. Average absolute inaccuracies between target and selected values per condition. Figure 3 illustrates how much brighter or darker the selected colors were compared to the target colors, while Figure 4 presents the absolute inaccuracies in brightness between the target and selected colors.

Table 2. Distribution of conditions where each participant achieved their smallest inaccuracy, and the corresponding average inaccuracy for those participants in that condition. Participants tended to show greater inaccuracies when the background brightness deviated further from the condition in which they performed best.

	Participants with smallest inaccuracy	Average Inaccuracy for Best-Performing Participants in This Condition
Brightness 13	2	2.31
Brightness 25	0	—
Brightness 38	1	3.24
Brightness 63	8	2.51
Brightness 75	7	2.53
Brightness 88	2	3.45

participants showing the lowest inaccuracy, brightness 13 produced the smallest average inaccuracy overall. In all cases, participants tended to show greater inaccuracies when the background brightness deviated further from the condition in which they performed best.

3.3 Discussion

As shown in Figure 3, participants tended to select darker colors than the target when the surrounding area was dark, and brighter colors when the surrounding area was bright. This result confirms that a phenomenon similar to brightness illusion occurred in the context of color selection.

According to Table 1, the brightness 63 condition yielded the smallest overall mean inaccuracy among all background conditions. However, for target values in the range of 0–9, the brightness 13 condition showed the smallest inaccuracy. Grayscale values in this low brightness range are especially difficult to discriminate, resulting in high inaccuracies across all conditions. However, when the background is dark, the contrast between the low-brightness selection and the background becomes more perceptually salient, which likely helped participants detect small inaccuracies more easily. Similarly, in the 90–100 target range, the use of bright backgrounds appears to have enhanced contrast, helping participants perceive discrepancies and reduce inaccuracy. Indeed, for target brightness values in the range of 90–100, there was a tendency for the inaccuracy to decrease as the surrounding brightness increased. If more accurate discrimination of these colors is desired within a color selection interface, it may be preferable to perform the selection against a surrounding color that is similar in brightness to the target.

Analysis of individual participants revealed inaccuracies in which background condition produced the lowest inaccuracy. Specifically, 2 participants had the lowest inaccuracy under brightness 13, none under 25, 1 under 38, 8 under 63, 7 under 75, and 2 under 88. These results indicate that the most appropriate background brightness for accurate color selection may differ across individuals. Taken together, these findings suggest that dynamically adjusting the background brightness of the color selection interface according to the user's characteristics and the target color could facilitate more accurate color selection aligned with the user's visual intention.

Figure 5 illustrates color selection trajectories of a participant, connecting the initial color selected by a participant (initial value) and the final confirmed color (selected value) for each trial. This figure shows an individual participant whose behavior clearly reflects the effects of brightness illusions. When the background was dark, this participant consistently selected final colors that were darker than bright targets (e.g., target brightness of 93 and 97 resulted in selections under 90 in the brightness 13 condition). Conversely, when the background was bright, dark targets (e.g., brightness 2 or 3) were matched with noticeably higher brightness values (e.g., above 5) in the brightness 88 condition. Furthermore, for high-brightness targets (90–100) under the brightness 13 condition, the participant's initial selections were brighter, but they adjusted them downward—suggesting that the perceived brightness of the initial color was exaggerated by the dark background. This behavior supports the interpretation that this participant was influenced by brightness illusion.

4 Experiment 2: Effect of Chromatic Surroundings and Display Size on Color Selection

4.1 Method

To examine the hypothesis that both the surrounding chromatic color and the display size of the selected color influence selection inaccuracy, we conducted a task in which participants matched an achromatic target color shown on a chromatic background using a color picker. Colors were represented in the HSV color space.

The experimental system, developed using Processing, is illustrated in Figure 6. The top of the screen displayed the target color, while the lower right contained a slider-based color picker, and the lower left showed the selected color surrounded by a chromatic color.

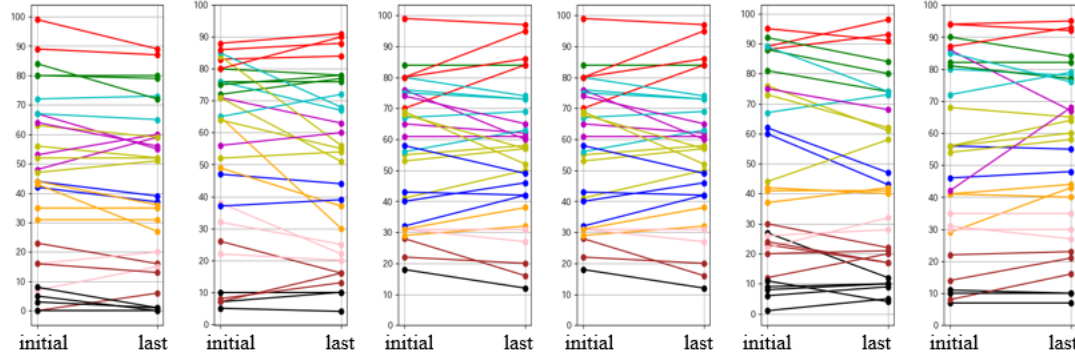


Fig. 5. Examples of trajectories affected by brightness illusion (from left to right: brightness levels 13, 25, 38, 63, 75, and 88). When the background was dark, this participant consistently selected final colors that were darker than bright targets. Conversely, when the background was bright, dark targets were matched with higher brightness values.

As in Experiment 1, each trial used a randomly generated target color, and the surrounding color and display size were varied across conditions. To avoid insufficient contrast between the experimental interface background (brightness value 50) and the target color, brightness values from 48 to 52 were excluded. Based on findings from Experiment 1, extremely bright or dark values were also avoided due to poor perceptual discriminability. Therefore, target brightness was limited to the range of 10–89 and divided into eight levels in increments of 10, with each brightness level presented an equal number of times.

Regarding surrounding color, we addressed the issue that the perceived brightness of chromatic colors varies by hue even when saturation and brightness values are matched. To control for this, we used ten principal hues based on the Munsell color system (R, YR, Y, GY, G, BG, B, PB, P, RP)[8], each with a brightness of 7 and saturation of 8, as they appear visually comparable. To reduce visual adaptation effects over repeated trials, we also included randomly interleaved trials in which the surrounding area consisted of a gradient of achromatic brightness values ranging from 0 to 100 (Grad condition). The list of colors used and the appearance of the gradient condition are shown in Table 3 and Figure 7. For the size of the selected color, we defined five conditions based on the side length of a square: 10%, 30%, 50%, 70%, and 90% of a square with a side length of 300 pixels (30 px, 90 px, 150 px, 210 px, and 270 px). These Display sizes are summarized in Figure 8. Each participant completed 440 trials, corresponding to all combinations of 11 surrounding color conditions, 5 sizes, and 8 brightness levels.

As in Experiment 1, participants were instructed to adjust the brightness of the selected color to match the target color. Prior to the experiment, each participant completed a brief color vision screening[34] to ensure normal color perception. Participants completed all trials in a single session, with a short break of 30 to 60 seconds provided after every 100 trials to reduce fatigue. The experiment was conducted in a well-lit indoor environment. Participants were seated directly in front of a computer monitor with standardized display brightness and maintained a consistent viewing distance of approximately 50 cm throughout the session. A total of 20 participants took part in the experiment (10 male, 10 female). The average duration of the experiment per participant was 50.5 minutes.

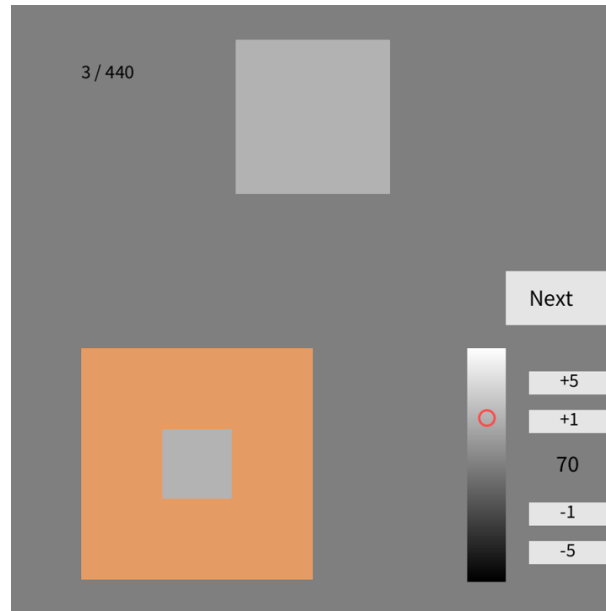


Fig. 6. Experimental Interface (Experiment 2). The lower left showed the selected color surrounded by a chromatic color, and display size were varied across conditions.

Table 3. List of colors used in the experiment.

	HSV	
R	(3, 39, 93)	
YR	(26, 56, 90)	
Y	(47, 67, 78)	
GY	(74, 58, 72)	
G	(153, 56, 76)	
BG	(174, 78, 76)	
B	(190, 71, 85)	
PB	(214, 67, 72)	
P	(274, 25, 85)	
RP	(342, 39, 99)	
Grad	—	Achromatic Gradation

4.2 Results

Before analysis, we removed outliers based on the inaccuracy in brightness between the target and the selected color. Specifically, values falling outside the range of the mean $\pm$ 3 standard deviations (SD) were excluded. Additionally, one participant was excluded from the analysis because their total task time was more than 2 SD below the mean task duration across all participants. As a result, data from 19 participants were used in the final analysis, yielding a total of 8,229 data points.

Figure 9 shows the average absolute inaccuracy for each surrounding color condition.

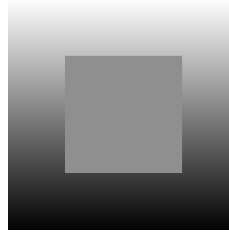


Fig. 7. Appearance in the Grad condition: the brightness of the surrounding area forms a gradient from top to bottom.

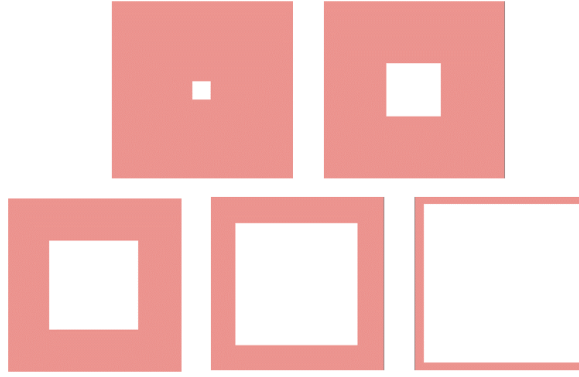


Fig. 8. Five size conditions: 10%, 30%, 50%, 70%, and 90% of a square with a side length of 300 pixels (30 px, 90 px, 150 px, 210 px, and 270 px).

Table 4. Inaccuracy by color grouped surrounding colors into three clusters. The group consisting of Y (yellow), GY (yellow-green), and G (green) showed the smallest average inaccuracy of 3.23

color group	differencies
R, YR, Y	3.56
Y, GY, G	3.23
G, BG, B	3.41
B, PB, P	3.48
P, RP, R	4.14

Among all conditions, PB (purple-blue) yielded the smallest average inaccuracy at 2.82, followed by the Grad (achromatic gradient) condition at 3.05. In contrast, RP (red-purple) showed the largest inaccuracy at 4.54, followed by P (purple) at 3.98.

To examine broader trends by hue category, we grouped surrounding colors into three clusters and calculated the average inaccuracy within each group. The group consisting of Y (yellow), GY (yellow-green), and G (green) showed the smallest average inaccuracy of 3.23, as shown in Table 4.

Figure 10 presents the average absolute inaccuracy for each size condition. The average inaccuracy was 4.76 for the 10% condition and 2.82 for the 90% condition. The results show that inaccuracy decreases as the display size increases. Similarly, the standard deviation of inaccuracy also decreased with display size. For the 10% condition, the standard

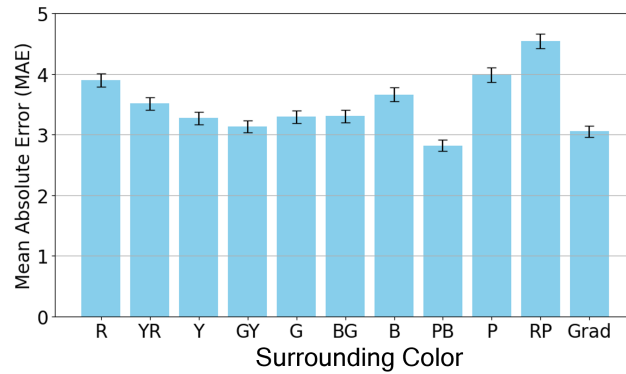


Fig. 9. Absolute inaccuracy for each surrounding color condition. The x-axis represents the hue of the surrounding color, and the y-axis indicates the absolute value of the inaccuracy.

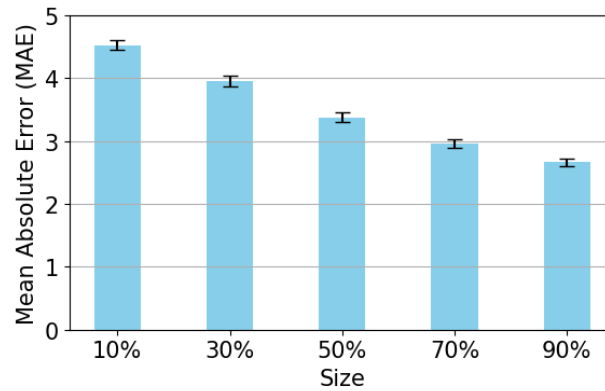


Fig. 10. Average inaccuracy for each size condition. The average inaccuracy was 4.76 for the 10% condition and 2.82 for the 90% condition. Average inaccuracy increased when the selected color was presented in a smaller area.

deviation was 4.65, while for the 90% condition it was 3.40. These findings indicate that both the average inaccuracy and the variability in responses were reduced when the selected color was presented in a larger area.

We define the number of selection adjustments as the number of times a participant changed the selected color within a single trial before finalizing their choice. Figure 11 shows the average number of adjustments for each surrounding color condition. The fewest adjustments occurred in the Grad condition, with an average of 3.67 adjustments per trial, while the most occurred in the GY (yellow-green) condition, with an average of 4.14. A Pearson correlation coefficient between the average number of adjustments and the average inaccuracy across surrounding color conditions was $r = -0.51$.

Figure 12 displays the average number of adjustments for each display size condition. The 10% size condition showed the fewest adjustments (3.28), while the 90% condition showed the most (4.28). The correlation coefficient between the average number of adjustments and average inaccuracy across display size conditions was -0.99 , indicating a strong

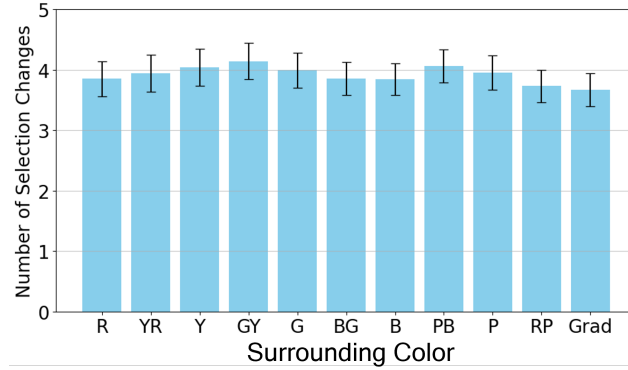


Fig. 11. Number of selection changes by surrounding color. The number of selection changes refers to the number of selection adjustments. A negative correlation was observed between the number of selection changes and inaccuracy across colors.

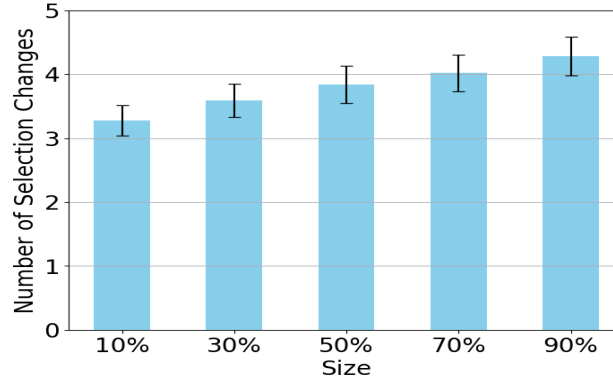


Fig. 12. Number of selection changes by displayed size. The Result indicates as the display size increased, participants adjusted their selections more frequently and achieved higher accuracy.

negative correlation: as the display size increased, participants adjusted their selections more frequently and achieved higher accuracy.

Each participant completed 440 trials. To examine learning effects as the trials progressed, we divided the trials into four blocks: trials 1–110, 111–220, 221–330, and 331–440. We analyzed the inaccuracy for each block, separating positive and negative inaccuracies. For positive inaccuracy, the average inaccuracies increased from 3.56 in trials 1–110 to 4.05 in trials 331–440. A paired t-test confirmed a significant inaccuracy at the 5% level. For negative inaccuracy, the average changed from -2.50 to -2.70 over the same periods, but the inaccuracy was not statistically significant. These results suggest that positive inaccuracy may increase as the trials progress. We also examined the number of selection adjustments as the trials progress. The average number of adjustments was 4.15 in trials 1–110, 3.63 in trials 111–220, 3.64 in trials 221–330, and 3.79 in trials 331–440. Only the first block (1–110) showed a notably higher number of adjustments—about 0.5 more on average than the other blocks—suggesting a brief initial exploration phase.

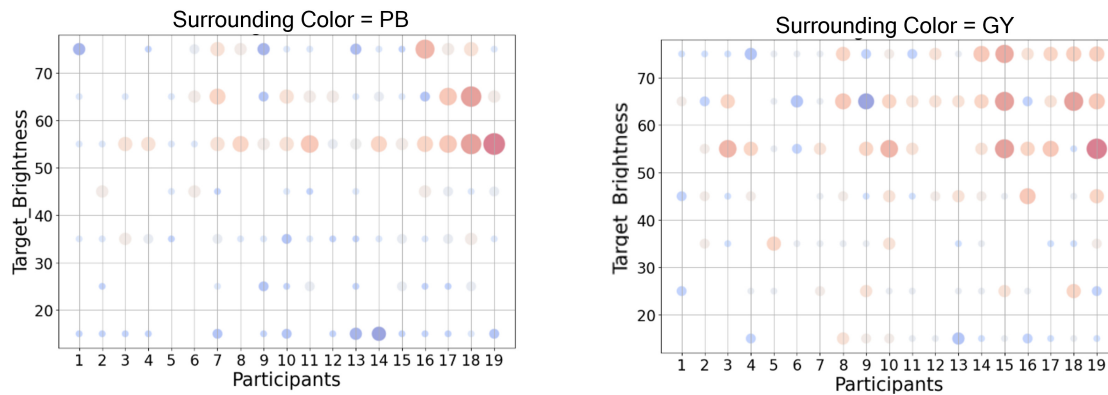


Fig. 13. PB (purple blue) and GY (green Yellow) condition. The x-axis represents individual participants (sorted in ascending order of mean inaccuracy), and the y-axis represents the brightness level of the target color. Inaccuracy brightness levels were grouped into eight ranges (10–19, 20–29, ..., 80–89), with their midpoints (15, 25, ..., 85) shown on the vertical axis. The plotted circles represent the median inaccuracy within each brightness range. Red circles indicate that participants selected a color brighter than the target, while blue circles indicate selections that were darker than the target. The size and saturation of each circle reflect the magnitude of inaccuracy—larger and more saturated circles represent larger inaccuracies.

4.3 Discussion

The results indicate that the PB condition and the group consisting of Y, GY, and G hues yielded relatively low inaccuracy. Figures 13 illustrate the signed inaccuracy in the PB and GY conditions, respectively. From these visualizations, we observe that in the conditions with low average inaccuracy, participants were able to select colors more accurately when the target brightness was below 50. There was also a consistent tendency for participants to overestimate brightness when the target was bright, and underestimate it when the target was dark. Compared to the achromatic surrounding color conditions used in Experiment 1, we found a similar trend in the results. Inaccuracy was lower when the target brightness was below the surrounding brightness. However, when the target was significantly brighter than the surrounding area, participants tended to select colors that were darker than the target. While direct comparisons with Experiment 1 are limited due to inaccuracies in trial count and participant groups, it is possible that the presence of chromatic backgrounds in this experiment influenced participants' perception when selecting bright colors.

In many conditions, a polarity consistent with brightness illusion was observed: darker targets were matched with even darker selections, and brighter targets with even brighter selections. These tendencies may also be partly explained by color assimilation, a phenomenon in which a color appears more similar to its surrounding colors than it actually is. In conditions where the surrounding chromatic color had a similar brightness to the target, participants may have been perceptually drawn toward the hue of the background, leading to systematic over- or underestimations. However, as shown in Figure 14, such a pattern did not hold in the Grad (gradient) condition. Because the surrounding color in this condition formed a continuous gradient, the perceived color likely shifted dynamically in relation to adjacent hues. This fluid context may have disrupted the contrast-based or assimilation-based patterns observed in other conditions, resulting in a weaker or inconsistent correlation between target brightness and the direction of inaccuracy.

The results showed that the larger the displayed area of the selected color, the smaller the inaccuracy in color selection. This may be attributed to the fact that when the color is displayed in a smaller area, the surrounding color

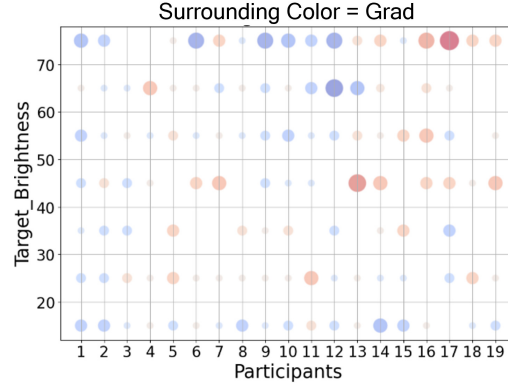


Fig. 14. Average inaccuracy in the Grad condition. The results indicate that the inaccuracy trend differed from that of the surrounding chromatic color conditions.

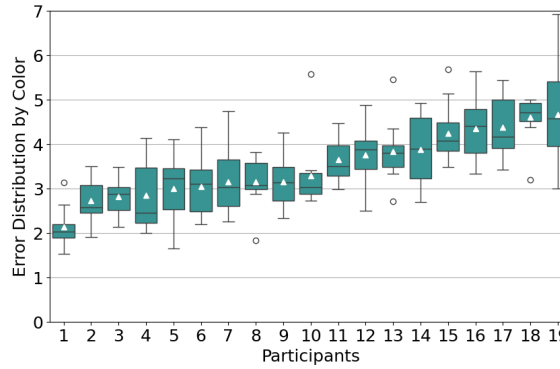


Fig. 15. Distribution of inaccuracy by color for each participant, sorted in ascending order of average inaccuracy. Individual inaccuracies in how inaccuracy varied by hue were generally small.

occupies a proportionally larger area, making it more difficult to visually compare the selected color with the target. This increased difficulty in visual comparison likely contributed to greater inaccuracy.

Figure 15 shows the distribution of inaccuracy for each participant. The figure indicates no strong correlation between interquartile range and average inaccuracy. Moreover, individual inaccuracies in how inaccuracy varied by hue were generally small. For example, no participant showed large inaccuracies in inaccuracy between the R (red) condition and its complementary BG (blue-green) condition. These observations suggest that hue inaccuracies may not significantly influence participant-specific inaccuracy patterns.

The correlation coefficient between participants' average inaccuracy and their average number of selection adjustments was 0.25, indicating a weak positive correlation. This suggests that participants with lower inaccuracy tended to make more adjustments, implying that refining color selections through repeated adjustments can help users converge on their intended color. On the other hand, as shown in Figure 12, the number of adjustments decreased when the display area of the selected color was small. This finding suggests that small display sizes may discourage users from making adjustments, potentially reducing their ability to fine-tune the color to match their mental image.

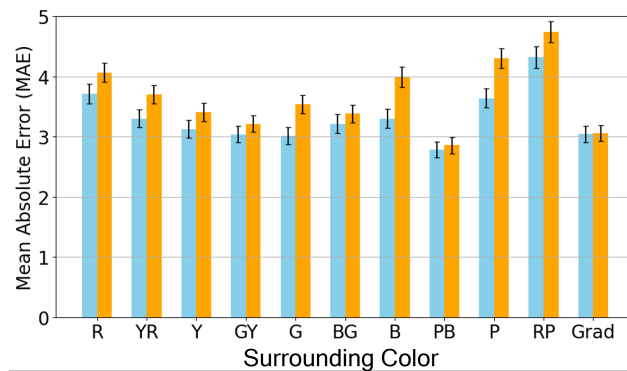


Fig. 16. Mean inaccuracy by color (by gender). Blue bars represent male participants, while orange bars represent female participants. Overall, there were no substantial inaccuracies in average inaccuracy between genders for most colors.

Figure 16 shows the average inaccuracy for male and female participants across different surrounding colors. Overall, there were no substantial inaccuracies in average inaccuracy between genders for most colors. However, in the range of Y to B hues, female participants exhibited greater variability in inaccuracy than male participants. One possible explanation for this observation is that, in general, females have been reported to possess superior color discrimination abilities in the yellow, green, and blue ranges compared to males [1]. This enhanced sensitivity may have contributed to a wider spread in responses, as female participants may have been more perceptive of subtle inaccuracies in brightness and thus more likely to adjust their selections.

The results revealed a negative correlation between the number of selection adjustments and inaccuracy across different surrounding color conditions, and a strong negative correlation across different display size conditions. These findings suggest that when the display area of the selected color is small, participants may be less motivated to adjust the color, leading to fewer adjustments and, consequently, greater inaccuracy. In the Grad condition, the number of selection adjustments was also relatively low. This may be due to the difficulty of perceiving the selected color accurately against the gradient background, which may have discouraged participants from attempting multiple refinements. The results also showed that as the experiment progressed, inaccuracy increased and the number of selection adjustments decreased. This pattern suggests a possible decline in participant focus or engagement in the later stages of the experiment, leading to less precise or more casual color selections.

5 General Discussion

This study investigated the influence of visual illusions in color selection interfaces, focusing on the effects of surrounding colors and brightness. Through two experiments, we identified key findings regarding how these factors affect users' color selection behavior. In this section, we discuss the implications of these findings for the design of color selection interfaces. We also consider the limitations of the present study and outline directions for future work.

5.1 Implications for Design

Our experiments demonstrated that brightness illusions do occur during color selection and can influence user behavior. Specifically, as brightness values become higher or lower, there is a tendency for the selected color to deviate in

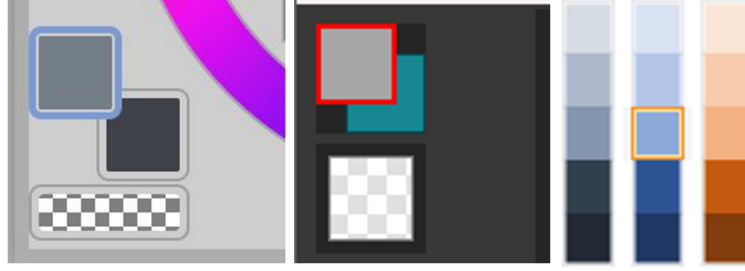


Fig. 17. Example of a selected color enclosed by a colored border.

brightness from the target color. This suggests that using extremely bright or dark background colors in color selection interfaces can lead to users unintentionally selecting colors that differ from their intended choice.

For example, dark mode settings commonly used in painting and design software may interfere with color selection by introducing brightness illusions caused by the dark background. This can result in users selecting colors that do not match their intended appearance. Some digital painting applications implement dark-mode interfaces by default. When using a dark interface, users may inadvertently select colors that appear accurate within the dark UI but result in unintended impressions once applied, particularly for bright colors. This mismatch may require users to revise their selections after noticing inconsistencies or, worse, may go unnoticed, leading to miscommunication of design intent. These findings suggest that disabling dark mode during color selection may help users better match their selections to how colors will be perceived in the final output.

While visual illusions are often treated as undesirable distortions in perception, our findings suggest that they can also be reframed as adjustable perceptual mechanisms. For instance, by deliberately tuning the background luminance or chromatic contrast in a color picker, designers could provide perceptual scaffolds that subtly guide users toward intended selections. Rather than eliminating illusions, it may be more effective to leverage them—transforming subtle perception biases into tools for supporting accuracy and expressiveness in visual design.

Next, the results of Experiment 2 suggest that smaller display areas for colors may hinder accurate color selection. Therefore, color candidates should not be displayed too small in the interface design. In color selection interfaces, the selected color tends to be displayed in a small area because it shares limited space with the color picker and other candidate colors. As a result, during actual usage, such as when users choose a color to apply to a design, the small display area may contribute to selection inaccuracies by hindering accurate perception.

In addition, color selection interfaces highlight the selected color by displaying a thin border around it. For example, in Figure 17, the selected color is enclosed by a thin red or blue outline. However, given that inaccuracy decreased when the area of the surrounding color was small relative to that of the displayed color, it can be inferred that these borders have minimal impact on perceptual inaccuracy. It is likely that the display area of the color itself, rather than the presence of a selection indicator, plays a more critical role in color perception accuracy.

5.2 Limitation

This study has several limitations that should be acknowledged.

First, the background color of the experimental system was fixed throughout the study. In actual design work, colors are applied over a variety of backgrounds, and thus the patterns of inaccuracy observed in this study may not generalize to all background contexts.

Second, the two experiments in this study were conducted with 20 participants who were not professional designers. Although we controlled the experimental environment, individual inaccuracies in color perception may influence the results, and it remains unclear whether the observed inaccuracies generalize to a broader range of users.

In particular, professional designers, due to their extensive experience with design tools, may already be aware of visual illusions in paint software and compensate for them during color selection. However, even for professional designers, color selection is a task that is deeply integrated into many stages of the creative process [17][40]. Therefore, color selection tools that take visual illusions into account are likely to improve both accuracy and workflow efficiency.

5.3 Future Work

While this study focused on achromatic colors, future research should investigate visual illusions in the selection of chromatic colors. For example, by observing how users select colors during real design tasks in paint software, it may be possible to identify more specific patterns of hesitation or inaccuracy in color selection.

Building on these findings, we aim to implement color selection interfaces that explicitly account for visual illusions. By deploying such interfaces and observing their use, we seek to develop tools that enhance both accuracy and intuitive usability, thereby supporting greater creativity in color-based design.

6 Conclusion

This study investigated the discrepancy between the perceived and actual appearance of colors in color selection interfaces, focusing on brightness illusions that arise from the color and size of the surrounding area. We conducted achromatic color selection tasks to examine how these visual illusions affect the accuracy of selected colors.

In the first experiment, we examined how varying the brightness of the surrounding area affected grayscale color selection, where participants adjusted colors displayed within surrounding areas of different brightness levels. Our analysis revealed that when surrounded by darker colors, selected colors appeared brighter, leading participants to choose colors that were darker than the target. Conversely, brighter colors caused selected colors to appear darker, prompting participants to choose brighter than target colors. These findings confirm that brightness illusions occur in color selection tasks and that the optimal background brightness may vary depending on both the selected color and the user. Furthermore, for participants who demonstrated distinctive selection behaviors, leveraging visual illusions to guide color selection may reduce the need for post-selection corrections.

In the second experiment, we examined the effects of the chromatic and size of the surrounding area on users' color selection behavior. The results showed that inaccuracies were lower when the hues ranged from yellow to green and when the selected color was displayed in a larger area, meaning the surrounding area was thinner. However, inaccuracies in hue did not appear to have a significant impact on inaccuracy.

These findings indicate that incorporating an awareness of visual illusions into the design of color selection interfaces can play an important role in improving color selection accuracy.

7 Acknowledge

The authors used ChatGPT solely for improving the clarity and readability of the English text. All scientific content, including the research design, analysis, and conclusions, was created independently by the authors.

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Received 20 February 2007; revised 12 March 2009; accepted 5 June 2009