DOCUMENT SUMMARY This research paper by Fialkowski and Schofield (2024) explores the application of color psychology to digital interfaces to improve user experience and increase Browse duration. The study investigates user preferences for color, dark vs. light modes, and the impact of specific color schemes on task performance and user comfort. Experimental results indicate that a teal-toned blue used in a dark mode interface was most effective at increasing user interaction and reducing perceived eyestrain.

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Considering Color: Applying Psychology to Improve the Use of Color in Digital Interfaces

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Abstract

Human-Computer Interaction (HCI) focuses on user-centered design, which leads towards innovative yet user-friendly technologies. This field overlaps with **User Experience (UX)** Designer and Research. The main difference is the theoretical foundation of **HCI**, which heavily weighs on psychology, principles, and theories. Color is an essential aspect of art and design; often designers overlook the connotations associated with color. This paper intends to connect the fields of **color psychology** and **HCI**, thus explaining how professionals in the field can utilize the advantages of this framework. To study the effects of color within the realm of digital interface design, an experiment was undertaken with the goal of increasing user session time. A hypothesis was derived by assessing demographics, preferences, and trends despite color being traditionally perceived as innately subjective.

> The data collected from the experiment demonstrated that yellow shades of blue, in combination with a noninvasive color scheme (such as dark mode), can increase the time users spend Browse a webpage.

Keywords: **Human-Computer Interaction**, **User Experience**, **Color Theory**, **Psychology of Color**, **User Interface Design**, **Digital Interface**

1. Introduction

The use of color in digital interfaces is a critical aspect of **user experience design**, influencing both the aesthetic appeal and functional **usability** of software applications. Empirical studies have demonstrated that color can significantly impact user performance and satisfaction. For instance, research indicates that appropriate color contrast can enhance readability by up to 40%, thereby reducing user error rates and significantly reducing eye strain and enhancing user comfort (Wright et al., 1997). Additionally, color coding has been shown to improve information retrieval times by 20% in complex interfaces. Color coding in navigation menus can decrease task completion times by 30%, as users can quickly identify and access desired functions (Pereira et al., 2022). These practical insights underscore the necessity of strategic color application in interface design, ensuring that digital products are not only visually engaging but also functionally efficient.

User Experience (UX) is an essential component of all products, and well-designed digital interfaces utilize rules and good-practice guidelines from the field of **Human-Computer Interaction (HCI)**. **UX** focuses on user-centered design, making sure that design decisions meet the needs of the user while also considering commercial goals. Often, a commercial goal includes holding the attention of the user to promote extended interactions. **UX research** aims to achieve a compromise between the commercial goals and accommodating the needs and preferences of the users.

Research is required within the field of **User Interface (UI) design** to determine how color plays a role in achieving the desired commercial goals. Applying previous **HCI** research knowledge to commercial goals can allow new discoveries in this field, and hence, help designers build interfaces that retain user interest. An understanding of the psychological influences caused by color choices within the **UI design** can help designers to influence user actions. For example, encouraging further Browse and increasing session time on websites and apps.

2. Color Theory

This literature review aims to provide a background to the **color theory** relevant to this paper, this includes a review of pertinent aspects of **color psychology** and color preferences. The literature review also describes the use of color in marketing and branding, and recent significant trends in color usage. This section finishes by describing specific features of web Browse, including user duration, color modes, and how color is used on webpages.

2.1. The Psychology of Color

Light illuminates the world, fills it with color, and brings life to objects due to the reflection of said light. More notably, color has a significant influence on the viewer; this study of the connotation of color is often studied under the field of **color psychology**. Academics who study color argue that color is more than just aesthetics, since it can communicate information based on learned associations of color and concepts (Elliot & Maier, 2007) and affect reasoning and behavior (Elliot & Maier, 2014). In the field of **HCI**, scholars study human behaviors, emotions, and motivations to investigate how humans achieve their goals when using digital interfaces. Hence, **HCI** researchers exploit the theory that color plays a role in decision making to design better interfaces.

Research has shown that it can be challenging to differentiate intrinsic color responses and learned experiences considering how color is understood to be taught (Rider, 2010). Color is often context-specific, and past research has shown that one color can have multiple, often

conflicting, interpretations. For example, red can be seen as implying both feelings of anger and passion (Elliot & Maier, 2014). Other foundational research suggests more innate responses to color exist; where brighter and saturated colors are often viewed as more pleasant and different color hues have associations of good, bad, strong, and weak (Valdez & Mehrabian, 1994).

Despite these contradictions, there is some generalized understanding of what a color means. Humans learn that a color of a specific hue is called red, then they learn that a red traffic light means stop and that a red oven plate is hot. Meanwhile, that same person may observe that blood is also red, therefore creating a correlation that red means danger while simultaneously being able to perceive it as a passionate color. Accepting the significance of color in design means that a designer can use color to convey an intended message.

2.2. Color Preference

Color is one of the first things most children are exposed to in the world; it is ultimately subjective and influenced by personal tastes and popular trends. However, colors also face a lifecycle of their own, due to emotional and biological changes over time that affect the determination of color preference. An understanding of the nature of these changes and preferences will help designers with their color choices within their interfaces.

Studies of previous research in this field have revealed a distinction between physiological reaction to a color and color preference, with red and yellow exhibiting greater arousal than blue and green, which are deemed more pleasant (Valdez & Mehrabian, 1994). Experiments investigating emotional and behavioral reactions to colors produced the following generic results (Adams & Osgood, 1973):

- **good** = white, blue, and green
- **bad** = black and gray
- **strong** = red and black
- **weak** = yellow, white, and gray
- **striking** = red
- **passive** = black and gray

Research has also shown that these preferences and reactions to color change over time and are often dependent on the participants' age. Results from previous experimental research have illustrated how color preference changes with age. Young children tend to favor red, blue, purple, orange, yellow, and green. After the transition into adulthood, with added maturity, the partiality switches to blue and green with a strong dislike for the color yellow (Guilford & Smith, 1959; Crozier, 1999).

3. Commercial Use of Color

Color plays a crucial role in commerce, impacting how customers perceive and interact with brands and products. It serves as a powerful tool for communication, attention, and emotional influence.

> Brands strategically choose colors to convey messages, evoke specific emotions, and differentiate themselves in a competitive market.

Color influences purchasing decisions, shapes brand perception, and enhances overall customer experience in commerce (Pelet & Papadopoulou, 2012). To further establish color's advantages, research analyzing icons concludes that consumers remember their attributes in the following order: colors, graphics, numbers, words (Wallace, 2013). This research reinforces the significance of color beyond aesthetics and shows how businesses apply **color psychology**.

3.1. Color and Branding

Many companies and institutions successfully utilize **color psychology** without the consumer being aware of the impact of color on their decisions and opinions. Brands meticulously select hues based on their psychological impact. Warm tones like orange and yellow evoke feelings of warmth, energy, and optimism, making them ideal for promoting leisure activities or food products. Research suggests these warm colors increase arousal and cause greater activity (Kurt & Osueke, 2014). Red, with its bold and attention-grabbing nature, often appears in fast-food logos, signaling urgency and excitement and making the consumer hungry (Valdez & Mehrabian, 1994).

Using lighter colors, such as white or light gray, in a logo or brand design can convey a range of positive attributes. White is often associated with purity, cleanliness, and simplicity, making it a popular choice for brands that want to project a sense of sophistication and minimalism (Valdez & Mehrabian, 1994). These vibrant hues can evoke strong emotional responses, making brands more appealing and recognizable. Additionally, bright colors can help differentiate a brand in a crowded market, making it stand out from competitors.

Cooler colors, such as green and blue, evoke calmness and reliability, fitting for eco-friendly brands or financial and healthcare services (Elliot & Maier, 2014). Blue, in particular, is considered a calm and peaceful color, associated with trust and integrity, and has been shown to increase productivity. Brands that often use blue are predominantly financial institutions, technology companies, medical providers, and multiple airlines. The blue color conveys messages of tranquility, relaxation, trustworthiness, security, and reliability (Rath, 2017).

Understanding cultural associations is also essential to ensure that colors resonate with diverse audiences. Moreover, cultural context plays a role where red symbolizes danger and heat in western contexts, red symbolizes luck and prosperity in Chinese culture. In an increasingly globalized marketplace, advertisers must navigate these nuances to create impactful interfaces that resonate across diverse audiences (Adams & Osgood, 1973).

3.2. Color Trends

The use of color in advertising has evolved significantly, reflecting broader societal trends and advancements in digital technology. In recent years, there's been a noticeable shift towards colors that evoke specific emotions and psychological responses, as discussed in previous sections. In recent years, many of the emerging color trends include shades that promote optimism and stability (León-Alberca et al., 2024). **Pantone** selects a trending color(s) each year through extensive consideration and trend analysis performed by **Pantone** Color Institute experts. This selection impacts product development and purchasing decisions in various fashion and consumer industries. For example, in 2021, **Pantone** selected two colors of the year: **Ultimate Gray**, a midtone, neutral gray, and **Illuminating**, similar to a ripe banana (Pantone, 2021).

Based on psychological **color theory**, gray is neutral and projects stability, while yellow is joyful and cheerful (Van Braam, 2021). However, Rider (2010) reported that yellow was the least liked color despite the happy hue attribute, observing that yellow was never selected over blue. A further study from Hemphill (1996) noted gray's association with poor weather conditions, thus generating negative responses. Furthermore, **Pantone** selects the color trend for a specific year, contrary to Birren's (1997) research theorizing that colors trend for three years.

Pantone's color choices of 2021 probably relied on some **color psychology** concepts to gauge a positive tone, perhaps taking the COVID-19 pandemic into consideration. Still, designers should not necessarily rely on these color trends despite light grays often being used as standard background colors in digital designs in many web and software applications. Although **Pantone's** chosen colors of the year do not have direct impact for interface design, popular and trending colors appear on website themes, regardless of **color psychology** principles. In contrast, digital interface designs are indefinite unless subjected to a nonpredictive redesign despite **UX trends** having a significant influence on interfaces.

4. Color and the Web

HCI focuses on user-centered design, and all design decisions should cater to the user experience. The web has developed a number of standard design principles, which change over time. With **Cascading Style Sheets (CSS)**, web developers can control the colors used on a site to accommodate the user experience by implementing the psychological theories discussed in the previous sections of this paper.

4.1. Research on Color and the Web

A large body of research has repeatedly demonstrated that users' attitudes were higher toward positive color conditions that use established psychologically known color effects on websites (Gorn et al., 2004). As a goal, one could relate all color-based design on websites as an attempt to relate with the audience, rather than viewing it as using color to achieve a level of psychology manipulation (Rider, 2010). In attempting to achieve this goal, many **UX** strategists recommend color utilization for aesthetics over user performance (Gabriel-Petit, 2007).

Color plays a crucial role in reducing eye strain on web pages by optimizing visual comfort and readability. Proper color contrast between text and background helps prevent visual fatigue, making it easier for users to read and process information without straining their eyes. Previous research has utilized web crawler tools to collect color data based on website usage and found the most utilized colors to be white, light gray, dark blue, medium blue, light blue, light yellow (cream tones), black, and gray (Kondratova & Goldfarb, 2007). Similarly, light grays and pastel shades are preferred as background colors and have been shown to lead to less eye fatigue (Deubel, 2003). High contrast, such as black text on a white background, can be harsh and tiring, while more balanced contrasts, like dark text on a light gray background, have been shown to be gentler on the eyes (Sandnes, 2017).

4.2. Light and Dark Modes

A current **UI trend** has several apps, websites, software, and operating systems implementing a **dark mode** interface by switching from dark text on a light background to a light on dark color scheme (Kim et al., 2019). Dark backgrounds were common in the '70s and '80s; this was not

due to an early **dark mode** adoption preference but instead mainly due to technology limitations. The relatively recent re-adoption of **dark mode** interfaces means that there is limited research on the impact of this interface mode. However, the work that has been done has attempted to utilize scientific data combined with **color psychology** principles to understand the implications and benefits of **dark mode** interfaces.

Eye strain and fatigue directly result from screen overuse, this is particularly prevalent with LCD screens (Sheppard & Wolffsohn, 2018). **UX research** has consistently demonstrated that although a **light mode** is often perceived by users as more user-friendly because the standard black text on white backgrounds provides maximum contrast; however, it may cause eye fatigue (Gabriel-Petit, 2007). Hence, **dark modes** have become a popular user preference, with researchers noting that individuals opt for **dark mode** claiming it provides a more satisfying experience (Eisfeld & Kristallovich, 2020).

> **Dark mode** is also reported to increase the time until users' eyes become strained due to less light being emitted (Kim et al., 2019).

Other benefits include that many users in low-light environments reported that they preferred **dark mode** (Kim et al., 2019). Also, many users who opted for **dark mode**, noted a feeling that it was "more natural" as if it was mimicking the lighting conditions of their environment (Eisfeld & Kristallovich, 2020). Research has reported that the use of **dark mode** significantly benefits battery consumption on OLED screens (Dash & Hu, 2021).

However, there are several negative effects on users based on the selection of **dark mode** interfaces. Users reading white text on a dark background require more time and experience greater difficulty in seeing the text, but comprehend the text faster (Wang et al., 2003). Color psychologists also warn against using predominantly black and black-like colors due to the association with aggression (Elliot & Maier, 2014).

4.3. Browse Duration

UX research aims to achieve a compromise between the commercial goals and accommodating the needs and preferences of the users (Benyon, 2014). Often, a commercial goal involves holding the attention of the user to promote extended interaction with a website. Moreover, designers must identify both the intent and results of standard practices to increase Browse duration. The increase in user time spent online has become a notable trend in recent years. According to recent data, internet users in the USA now spend an average of over eight hours online daily, marking a significant rise from previous years. This increase can be attributed to various factors, including the proliferation of digital media, the rise of remote work and online education, and the growing importance of social media and streaming services in daily life (Statista Research Department, 2021; Mogaji et al., 2023).

Notwithstanding, studies have repeatedly shown that the growth in web activity is predominantly attributed to more frequent and not prolonged Browse sessions. Many users leave a newly visited website within 10-20 seconds (Montgomery & Faloutsos, 2001; Nielsen, 2011). It should be noted that there is a significant difference between grasping the user's attention and maintaining it. In fields such as entertainment, retail, and education, **UI designers** can use **color psychology** research as one of the tools to improve user retention on websites. One possible way to increase the time spent on a site involves reducing user eye strain and applying **color psychology** to create relaxation for the users (Gorn et al., 2004).

5. Experimental Methodology

This research aims to determine how color's psychological principles influence users' interest when Browse to increase retention and suggest what color to implement on websites to achieve that goal, thus generating three core research questions required to create this style guide.

1. The first research question is to understand user preference for **dark mode** with varying demographics.
2. The second research question evaluates **color psychology** to assess color trends compared to preferences.
3. Lastly, the third research question asks if color can increase the time users spend Browse websites.

5.1. Experimental Approach

This study will determine what styles should be applied to websites to increase Browse time based on **HCI theory** and **color psychology** principles. A prototype website was then created to use experimentally to test the impact of color on a range of users. This study aims to create guidelines for designers to understand color choices and better achieve commercial goals and help set a foundation for future color research applying **color psychology** to website design. This study utilizes a quantitative research method to collect a range of data, focusing on how long a user can spend Browse a website in **dark mode** compared to **light mode**.

5.2. Data Collection

The experimental hypothesis proposed that **dark mode** with a teal shade of blue would induce the most extended Browse times. A user survey regarding **dark mode** was used to understand each participant's current **dark mode** usage and to gain insights into the decisions they made when they chose to opt-in or opt-out of **dark mode** before the main experiment. The participants then browsed a prototype website (built with Figma) in various dark and **light mode** color schemes featuring twenty-five paragraphs of Lorem Ipsum text in size 25pt Roboto font. Hidden throughout the text are the names of random animals, the participants were asked to speak out loud and name the animal they find.

Table 1: The ninety animal names participants had to identify in the experiment. | | | | | | | :--- | :--- | :--- | :--- | :--- | :--- | | Fox | Centipede | Turkey | Otter | Elk | Chinchilla | | Seal | Badger | Possum | Walrus | Hyena | Squirrel | | Wolf | Zebra | Chicken | Crocodile | Gecko | Meerkat | | Raccoon | Quail | Turtle | Eel | Iguana | Monkey | | Yak | Ferret | Aardvark | Beaver | Guppy | Snake | | Lemur | Seahorse | Vulture | Jaguar | Giraffe | Elephant | | Camel | Mule | Scorpion | Peacock | Hamster | Deer | | Kangaroo | Gorilla | Antelope | Caribou | Goose | Koala | | Octopus | Sheep | Wasp | Panther | Lobster | Goat | | Llama | Mole | Reindeer | Pig | Manatee | Ostrich | | Squid | Sloth | Boar | Penguin | Lion | Toucan | | Platypus | Cougar | Ant | Jackal | Lizard | Pelican | | Rabbit | Rat | Mouse | Mink | Slug | Salmon | | Bear | Frog | Eagle | Donkey | Duck | Flamingo | | Moth | Puma | Squid | Dog | Tortoise | Cat |

Table 2: An example of the colors in a set of randomized prototype webpages. | Background | Text Color | | :--- | :--- | | Black background (control) | White text | | White background (control) | Black text | | Dark gray background | Light gray text | | Light gray background | Black text | | Navy blue background | Pale yellow text | | Light blue background | Dark teal text | | Teal background | Pale yellow text | | Yellowish-gray | Dark teal text |

6. Experimental Results

The following section describes the results of the experimental study to test how color can increase Browse time on websites.

6.1. Demographic Metrics

The study consisted of 32 participants, evenly split in gender, with ages ranging from 18-74. Unlike most other research in the field, information on the participant's personality type was collected. This data showed that 53% of the participant cohort identified themselves as introverts. The personality type attribute was viewed as a primary classification variable for the participants in the data analysis.

6.2. Dark Mode Preference

A preliminary questionnaire was distributed to the study participants to understand people's assumptions and attitudes towards **dark mode**, **light mode**, and colors. Most of the participants liked **dark mode**, with only a single response suggesting they did not prefer **dark mode**, yet did not dislike it. However, 81% of participants expressed indifference towards **light mode**, or reported that they did not like it.

*Figure 1 shows that **dark mode** was overwhelmingly preferred by males. A large percentage of males strongly liked **dark mode** (75%) and the remaining 25% still liked **dark mode**. These figures compare to 50% of those reporting as female strongly liking **dark mode** and 19% liking **dark mode**.*

The collected data indicates that those who identified as both female and introverted were 100% supportive of **light mode** compared to only 29% of extroverted females. All of the participants who were aged 45 and over based their **dark mode** preference and usage on other human influences in their lives, such as children. These participants were heavy **dark mode** users.

6.3. Color Trends and Personal Preference

Figures 2 and 3 show that 65.6% of participants used iOS for their cell phone operating system, while 34.4% used Android. For computer operating systems, 65.6% used Windows and 34.4% used macOS.

Android users liked and strongly liked **dark mode** more than all other groups at 91%. **Mac** users were the second-largest **dark mode** supporters at 81%. Those participants who favored Autumn and Winter seasons preferred **dark mode** 100% of the time.

Shades of blue were the favorite colors of 72% of participants, and 97% of participants either said a shade of blue is their most worn, most purchase, favorite, or second favorite color. All of the participants who choose black as a favorite color always used **dark mode** when it was available. Conversely, 90% of those who choose white as their favorite color rated **light mode** the highest compared to other participants. Yellow and orange were the least liked colors, with 56% and 28% selected as the least favorite color of the participants, respectively.

6.4. Time Spent Browse

The participants could spend as little or as long on a page as they deemed necessary to find the animal names hidden throughout the text.

Table 3: Average time spent Browse on each webpage, with varying background colors. | Page color | Time on page | | :--- | :--- | | Black (control) | 9 minutes 11 seconds | | Dark Gray | 5 minutes 0 seconds | | Navy Blue | 4 minutes 47 seconds | | Teal | 9 minutes 30 seconds | | White (control) | 5 minutes 35 seconds | | Light Gray | 4 minutes 54 seconds | | Light Blue | 9 minutes 48 seconds | | Yellowish-Gray | 6 minutes 5 seconds |

6.5. Accent Colors

The longest time spent on a page, based on accent colors, were blue, purple, red, green, pink, orange, and yellow, respectively. Moreover, the most animal names spoken out loud by the participants were when the colors were ranked from blue, red, green, orange, purple, pink, to yellow.

6.6. Correlated Results

The navy-blue page had the least time spent on the page at 4 minutes and 47 seconds. The participants found an average of 44 animals, and it only took an average of 6.5 seconds for each animal, which is the shortest time per animal found.

During post experiment interviews, all of the participants said that the white page was their least favorite. Participants spent an average of 5 minutes and 35 seconds on the webpage, and found an average of 34 animal names. The participants took the longest time (without asking to re-read the page) to find the animal names on the yellowish-gray page.

The most time spent on a page was 9 minutes and 48 seconds on the light blue page. This page also had the least amount of animals found, only averaging 26 animal names. The participants repeatedly browsed this page, and they spent an average of 22.5 seconds to find each animal name.

> The most animals found were on the teal webpage, with an average of 64 animal names found. The average time on the page was 9 minutes and 30 seconds, and the participants averaged 8.9 seconds to find each animal name. In the post-experiment interview, all of the participants stated that the teal page was the easiest, hurt their eyes the least, and was their favorite page to browse.

7. Data Analysis

The data collected was analyzed using independent t-tests to determine if the time spent on the page increased based on background and accent colors. The aim was to discover color combinations that reduce errors and increase readability, and hence affects the time spent on the page.

7.1. Dark Mode

The research gathered during this study supported the previous experimental results of other researchers in the field. These researchers also found that their users preferred **dark mode**

both for the tangible **usability** benefits and because current trends had led to it being more popular. **Dark mode** was available on **Android** devices much earlier than on **iOS**. The data collected revealed that **Android** users were generally more outspoken about their desire for **dark modes** on their devices and apps. In contrast, many participants who used **iOS** based devices revealed that they opt for **dark mode** solely because they believe it is "trendy", or they had heard "**dark mode** is better". Therefore, it is a reasonable prediction to make that **dark mode's** popularity could diminish as time progresses.

7.2. Color Preferences

Previous research has repeatedly demonstrated that people respond to color preference; in reality, most of the preference is generally towards the same color. Within this experiment, the participants overwhelmingly responded positively towards the color blue. In contrast, there was a distinct animosity from participants towards the color yellow. More research is required to better understand why the majority of users favor blue and dislike yellow within digital interface.

7.3. Browse Time

This experiment has demonstrated that color can promote longer Browse sessions on webpages. The recommended style guide established from analysis of the experimental data, is a **dark mode** teal color. This combination was found to reduce eyestrain among the participants and was also considered as noninvasive by the experimental participants. However, the color teal did not generate the longest Browse time on individual prototype webpages. The light blue background had the participants Browse for an average of 18 seconds longer than the pages with a teal background.

8. Conclusions

This paper described experiments which attempt to understand the importance of **color psychology** within **HCI**. Color was shown to be a vital asset because it sets a tone and creates a pleasurable viewing experience for the user. Blue was shown to be predominantly the most liked color with the most beneficial psychological functionalities. At the same time, yellow should not be considered for digital interfaces, but is often necessary due to branding and commercial limitations.

> The experimental results suggested that color, more particularly a teal-toned blue, can influence users to spend more time Browse on websites.

The experimental results also correlated with the results of previous research, demonstrating that **dark mode** has a number of **usability** benefits. The research indicates that **dark mode** should remain as an interface option, but its use is potentially debatably shifting, as it becomes less of a "recent" trend.

8.1. Experimental Limitations

The scope of the research and timeframe to test participants was necessarily restricted by practical constraints and this resulted in a few limitations for the study. Since the background colors tested were grayscale and blue hues, this meant that the possibility of a participant's favorite color and the psychological impact of other colors was not considered as a

circumstance of variation. This experiment solely focused on promoting eyestrain through detectable text to shorten the duration of each individual participant's testing session. By introducing other web components, users reactions and responses to the page may differ when the page contains more items than just textual elements.

8.2. Future Work

The data from the study creates a foundation to support the use of **dark mode** and teal accented colors in digital interfaces to reduce eyestrain and improve the user experience. The study should be extended to include a wider spectrum of colors while still focusing on colors that have a warmer tone (such as teal). Any further research should also include A/B testing of slight color variants, providing insight into real-world website applications and pinpointing if an exact color code value can universally serve as an adjustment rate among hues.