“Is dark mode better than light mode?”: Comparing Effects of Light and Dark Modes on Reading and Memory Recall

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ABSTRACT

In recent years, the inclusion of “dark mode” has increased on many interfaces and computer applications in our current digital age. Dark mode, which is the use of light text on a dark background, had previously been studied and compared to its more commonly used counterpart, “light mode,” which uses dark text on a light background. This study set out to further explore the benefits of using either dark mode or light mode in digital interfaces, particularly its effect on reading comprehension and memory recall. A controlled experiment was designed to measure the efficiency with which participants could recall and comprehend different forms of text.

Participants started with either dark mode or light mode to read several pieces of text and were then tasked with answering questions to gauge their understanding and memory of each text. The participants were also asked about personal preferences. The results indicated a trend in rising personal preferences for dark mode. Additionally, the experiment test results showed no major differences between dark mode and light mode, except for one advantage: lower error rates in memorization for dark mode.

Keywords

dark mode, light mode, memory recall, speed reading, user interface design, user experience, memorization

INTRODUCTION

In the ever-evolving landscape of digital technology, user interface (UI) design is a vital component where the interaction between aesthetics, usability, and functionality profoundly influences the user experience. Among the myriad of design choices, one critical factor has taken center stage in recent years, sparking fierce debate and discussion in the tech community: the choice between light and dark modes for computer screens. This design debate, often taken for granted, has the potential to affect users' productivity, reading comprehension, speed, and memory retention in unique and complicated ways.

The contemporary digital age has seen a dramatic shift toward screen-centric activities, as we spend more and more time in front of computers, smartphones, and tablets. With this paradigm shift, the graphical design of the interfaces that mediate our interactions with technology has emerged as an area of profound importance. Light mode has long been the default choice for desktop displays and applications. Its popularity is deeply rooted in the history of graphical user interfaces and design principles that emerged in the early days of computing. As personal computers began to gain popularity in the 1980s, graphical user interfaces (GUIs) became an integral part of the computer experience and the fundamentals of interface design.

One of these fundamental design principles is the concept of WYSIWYG (What You See Is What You Get), which aims to make on-screen content look as much like printed material as possible. In keeping with this principle, light mode is the logical choice due to its similarity to traditional printed text on white paper. It offered high contrast and legibility, making it easier for users to read text and interact with graphical elements. Moreover, the choice of light mode as the default option was influenced by considerations of accessibility and universal design. Light mode traditionally provided a readable and inclusive interface that catered to a wide range of users. From a psychological perspective, light modes are also considered more attractive and professional. It is associated with clarity, purity, and efficiency. In productivity and office software, it conveys a sense of seriousness and authority. User familiarity with the light mode further cements its status as the default option for the majority of applications, operating systems, and websites. The preference for light mode is seen as an embodiment of design conventions that prioritize readability, accessibility, and user familiarity. However, as technology advances and our understanding of user experience deepens, the previously undisputed dominance of light mode is being scrutinized and reassessed.

In recent years, dark mode has become popular as an alternative to traditional light mode. The rise of dark mode can be attributed to a number of factors that have resonated with users and developers. One of the main benefits of dark mode is its capacity to diminish eye

strain, particularly in dimly lit situations or at night. The sharp difference between a shining screen and a dull environment can cause distress for many users, leading to eye strain. Dark mode helps in alleviating this issue by employing a dim foundation and lighter content. Dark mode is said to improve focus and reduce distractions. The display's subdued colours and reduced brightness can promote concentration, making it an appealing choice for tasks that require deep focus like editing, writing, coding, etc. Lastly, by reducing the amount of blue light emitted from screens, the dark mode can be a more sleep-friendly option, which is important in a world where many users interact with screens late into the night.

The rise of dark mode as an alternative and the ongoing debate about its merits means there is a growing desire for options that cater to user preferences and different use-case scenarios. In this context, the default choice of lighting mode becomes a fascinating point of exploration as we seek to understand how and why it emerges and how its dominance influences how we perceive and interact with digital interfaces. Despite the prevalence of dark mode in today's digital environment, a comprehensive understanding of its impact on user performance, compared to a well-established light mode, remains elusive.

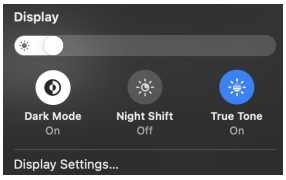

Figure 1. Screenshot of display in dark mode

This paper aims to fill this gap by delving deeper into the complex relationship between light mode, dark mode, and reading comprehension, speed, and memory. Specifically, we will investigate the following key questions:

1. How do light and dark modes influence reading comprehension and retention?
2. Can the selection of light or dark mode significantly affect memory recall and overall cognitive load during extended computer use?

By addressing these questions, we aim to provide a comprehensive understanding of the light vs. dark mode debate, enabling designers and developers to make more informed choices in crafting user-friendly interfaces. This paper aims to prove/disprove the claim that dark mode has an effect on reading comprehension/speed and memory retention. This research holds the potential to unlock innovative design strategies that not only cater to users' aesthetic preferences but also enhance their overall cognitive performance, thereby advancing the field of human-computer interaction in the digital age.

Related Work

There is a multitude of research and work related to the study of the use of dark mode and its effects on readers. A relatively recent conference paper, “User Interfaces in Dark Mode During Daytime – Improved Productivity or Just Cool-Looking?” discusses the rise of the actual term “dark mode” and highlights Google Trends data showing this phenomenon in the summer of 2018[4]. Despite the differences in the terminology used in the past and more recent years, many studies have attempted to measure the different strengths and weaknesses of using dark text on a light background versus light text on a dark background.

The study of a dark vs. light mode has been measured in different ways by different researchers. A list of ways that light and dark mode text can be compared includes visual acuity/ readability, retention, fatigue and perceived effort, and aesthetic and personal preference ratings. There are some different considerations and ongoing debates as to whether dark mode is better than light mode, depending on the factors considered.

The oldest relevant discussion found was from Hall and Hanna 2004[2], where it was found through experiment that there was a clear indicator that light mode was better for keeping attention, but in addition, an “aesthetic rating” was also recorded in their study in which dark mode had a high rating that was unexpected by the researchers.

Piepenbrock et al.[5] also directly compared a dark mode and a light mode, measuring them with several tasks like proofreading and participant ratings of legibility. They found positive results for light mode at smaller text sizes but less significant differences for larger text sizes.

Perceived effort in reading dark mode versus light mode text is discussed with Sethi and Ziat[6], where they identify and propose that dark mode is perceived as requiring less effort. They also point out that the environment around the reader (ex., a dimly lit room versus a well-lit room) affects reading differences in light mode versus dark mode as well.

Finally, a moderate middle ground is discussed with Kim et al. [3], where different ‘optimal’ uses are discussed for dark mode and light mode depending on the situation, and it is suggested that dark mode is better for tasks that need to be sustained, but low levels of attention and light modes are better for shorter focused efforts.

In addition to the fact that different characteristics are measured between different studies, the results of these studies still leave in contention which is the ‘best’ display type to use. As an insertion into this ongoing discussion, this should provide some clarity on how exactly dark mode may or may not be beneficial to readers of the text.

METHOD

Participants

The study involved twenty participants who volunteered without any incentive for their participation. Each participant was required to have prior experience with a computer or laptop and be able to interpret a small passage in English. For initial survey purposes, ten

participants were predominantly dark mode users, whereas the remaining ten participants were predominantly light mode users. The study targeted participants between the ages of 18 and 40, representing a portion of the population of adults who spend a large part of their day in front of a screen. Other demographic information about the participants was not relevant to this study, as the focus was not on a particular gender or race.

Apparatus

There were a couple of key apparatuses used. The first was a 13-inch MacBook Pro laptop with a screen size of 11.97 x 8.36 inches and a macOS operating system, which had been pre-set to the light mode versus dark mode comparison program for the study. Second, a timing device, a stopwatch, was used separately from the laptop to conduct the study. Thirdly, questionnaires were administered via electronic forms in Google Docs to the participants after each experimental set to collect both quantitative and qualitative data. Additionally, a consent form using Google Forms was provided to the participants to consent to participate in the study. Lastly, Google Docs was used to conduct both memorization and speed reading tasks and to record the results.

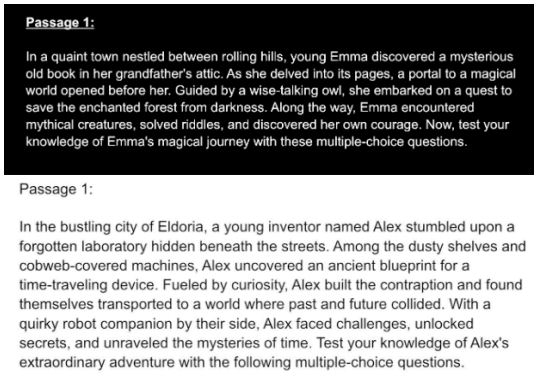

Figure 2. Passage for level 1 in dark and light mode

Procedure

All apparatus was sterilized periodically between each usage and reset to ensure data collection was as unbiased as possible. The purpose of the experiment was explained to the participants. Each participant was seated in front of the laptop and was familiarized with the task until they were prepared to proceed. The first ten participants performed in dark mode, while the remaining ten participants performed in light mode. The process was repeated with the first ten participants starting with light mode while the other ten with dark mode to ensure a counterbalancing effect. The task assigned to them in the first level involved memorizing names and small numbers, while random characters were the focus of the second level. The time taken and the number of correctly memorized answers were recorded.

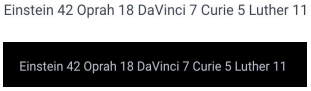

Figure 3. A memorization task for level 1

Figure 4. A memorization task for level 2

The participants were directed to perform the speed reading method. The time taken for their readings and the accuracy of their answers in the questionnaires were recorded. The time required for the participants to comprehensively read and grasp the information was recorded for both the first and second levels, with the first level expected to be comparatively easier than the second level. It is important to note that the passages at both levels were designed for easy comprehension within the participants' knowledge. After the completion of each level, a questionnaire was distributed to the participants based on the passage they had read, and the number of correct answers was recorded.A post-screening survey about their preferences regarding light and dark modes, as well as the reasons for their choices, was recorded.

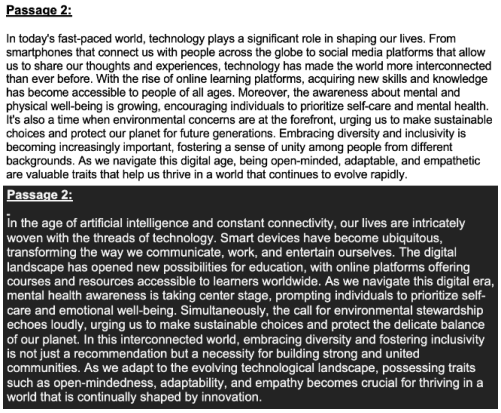

Figure 5. Passage for level 2 in dark and light mode

Design

The study employed a 2 x 2 within-subjects design with the following independent variables and levels:

Mode: Light mode, Dark mode

Level of difficulty: 1, 2

This user study was conducted using two methods memorization and speed reading. There were two dependent variables: task completion time, measuring the time taken for each participant to complete the assigned tasks for both memorization and speed reading methods, and accuracy, measured in error rates. For memorization, accuracy pertained to the number of responses that did not match the provided sentences, while speed reading, referred to the number of incorrect responses obtained from the questionnaire at the end of the task.

Each participant was tested on both memorization and speed reading at two levels of difficulty in both light mode and dark mode. With 20 participants tested, there were a total of 20 participants x 2 methods x 2 levels x 2 modes = 160 trials.

RESULTS AND DISCUSSION

The main results of interest for both the memorization and speed reading methods were the performance measures related to task completion time and error rate. The subjective impressions of the participants regarding the two methods were also of interest.

Memorization

The grand mean of task completion time in memorization was 21.94 seconds. The mean task completion time for the light mode was 21.5 seconds, while the mean task completion time for the dark mode was 22.4 seconds, representing a 4.2% longer in dark mode compared to light mode. This finding suggested that participants exhibited better memorization performance in light mode than in dark mode, although the observed mode effect on task completion time did not reach statistical significance ($F_{1,19}$ = 0.326, ns). With a p-value of 0.5745, significantly larger than 0.05, the interval included zero with 95% confidence. Consequently, there was insufficient evidence to reject the null hypothesis, indicating no significant difference in task completion time between light mode and dark mode. The lack of a notable difference may stem from participants abandoning efforts to recall memorized information, leading to a quicker task completion time.

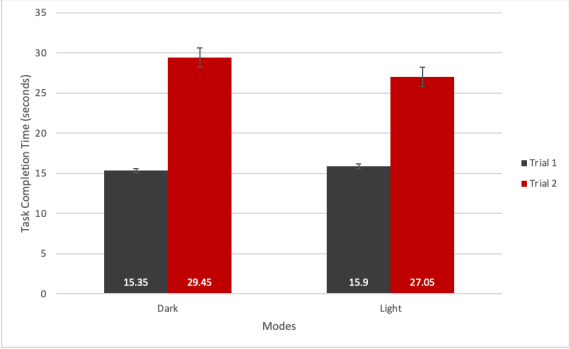

Figure 6: Task Completion Time (seconds) by Modes for Memorization

The grand mean of error rate in memorization was 22.75%. Light mode with a mean error rate of 25.9% exhibited an approximately 32.1% higher error rate than dark mode with a mean error rate of 19.6%. The effect of modes on the error rate was determined to be statistically significant ($F_{1,19}$ = 5.668, p < .05). The p-value of 0.0279, which was significantly smaller than 0.05, provided 95% confidence that the difference was not equal to zero. Consequently, the null hypothesis, which posited that the error rates between dark mode and light mode were equal, was rejected. This finding indicated that participants were more prone to making errors in light mode than in dark mode. The significant difference in error rates between dark mode and light mode could be attributed to the majority of participants preferring dark mode over light mode. Those who preferred dark mode were more experienced in using it than in light mode, thereby reducing the likelihood of participants making errors in dark mode.

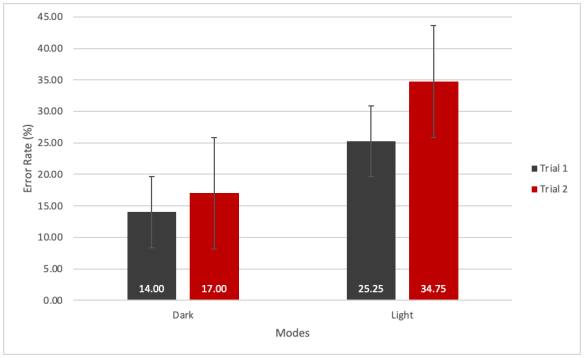

Figure 7: Error rate (%) by modes for Memorization

Speed Reading

The grand mean for task completion time for speed reading was 47.2 seconds. The mean task completion time for light mode was 47.9 seconds, which was about 2.8% longer than the mean of 46.6 seconds for dark mode. This suggested that speed reading was performed faster in dark mode than in light mode. From the ANOVA test, the result of the effect of modes on task completion time was ($F_{1, 19}$ = 0.569, ns). With a 95% confidence level, the null hypothesis was not rejected because there was no significant evidence to show a difference in the mean of task completion time between light mode and dark mode. The lack of a significant difference in speed reading completion time may be attributed to the multiple-choice questionnaire, which focuses on surface-level understanding rather than deep comprehension.

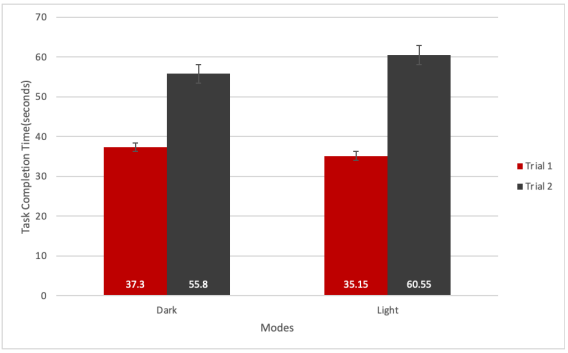

Figure 8: Task Completion time (seconds) by modes for Speed Reading

The mean error rate for light mode was 27.5%, which was 5.8% higher than for dark mode with a mean of 26%. The results showed that a higher number of errors in speed reading occurred in light mode compared to dark mode. However, the difference between light mode and dark mode in error rate was not statistically significant ($F_{1, 19}$ = 0.125, ns). The absence of a significant difference in error rates in speed reading could be attributed to the presence of a multiple-choice questionnaire, which may have led to guessing based on the content. Therefore, some of the correct answers could have resulted from guessing.

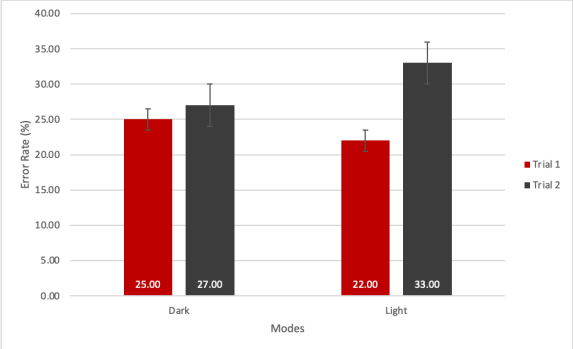

Figure 9: Error rate (%) by modes for Speed Reading

Participant Feedback

The majority of the participants preferred dark mode over light mode. The results showed that most younger participants expressed a preference for dark mode, while older participants favoured light mode.

Participants preferring dark mode cited reasons such as "*looked better aesthetically*", "*it was easier on the eyes*", and "*errors were easier to correct when coding*".

On the other hand, participants preferring light mode held different opinions, mentioning reasons such as "*was easier to read*", and "*the default setting was light mode*".

CONCLUSION

From the results and discussion section, it is clear that the null hypothesis can be rejected and concluded with a couple of key factors. The first is that an age-related preference pattern does exist amongst the sample population studied. Specifically, a 30-year-old cutoff exists, whereby those in the younger cohort (aged < 30 years old) preferred dark mode and those in the older cohort (aged > 30 years old) preferred light mode. There is also the power of default settings, which was reinforced as a trend due to the use of light mode as the default option, which has been demonstrated to be statistically significantly preferred. This finding underscores the importance of default choices in shaping user experiences. As a result, future work in this domain should extended beyond functional testing. Future tests should involve aesthetic aspects of light and dark modes. Furthermore, exploring the impact of blue light filters, especially in the context of late-night content consumption, is an avenue for further investigation.

There is also the issue of enhancing the inclusivity of design so that improvements can be focused on increasing the diversity of usability testing, extending testing durations, and enlarging sample sizes. Introducing age-specific interfaces that offer users the choice between light and dark modes based on age could contribute to a more personalized and user-friendly experience. The insights gained from this study also highlight the potential of default settings to improve accessibility. There can be an enhancement of attention for user systems with age-specified default settings, which can overall play a profound role in increasing the accessibility of software.

As for the contributions of this study, it is essential for maximizing the engagement of websites and applications. Tailoring the default mode based on the user's activity can be a powerful strategy for increasing user interaction. Lastly, this study adds evidence for the temporal theories of UI, specifically the concept of 'Technological Inertia,' where the method of technology usage tends to persist over time with high persistence and low adaptation or habituation. Overall, our insight from this study emphasizes the need for thoughtful consideration of default settings to have a lasting impact on user engagement and long-term behavior.

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