Impact of High-Contrast Color Schemes on Reading Comprehension and Eye Movement: An Eye-Tracking Study

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ABSTRACT

This study investigates the impact of high-contrast color schemes on reading comprehension and eye movement behavior in adults using eye-tracking technology. The experiment contrasts a non-standard color scheme (yellow text on a green background) with the traditional black-on-white text to assess its effects on visual engagement and cognitive load. Key eye-tracking metrics such as fixation duration, saccade amplitude, and regressions were analyzed to evaluate how participants' visual processing differed across conditions.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**.

KEYWORDS

eye tracking, visual attention, cognitive load

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1 INTRODUCTION

In today's digital world, reading on screens has become a ubiquitous activity, with diverse color schemes often employed to improve readability and visual comfort. While the conventional black-on-white text remains a standard, high-contrast color schemes, such as yellow text on a green background, are occasionally proposed as alternatives, particularly for users with visual impairments or under specific lighting conditions. However, the impact of such non-standard color combinations on reading comprehension and eye movement behavior remains insufficiently understood.

Eye-tracking technology offers a powerful tool to investigate how visual information is processed, providing insight into cognitive load and engagement through metrics such as fixation duration, saccade amplitude, and regressions. These metrics, in combination with reading comprehension assessments, can reveal how different visual presentations of text influence not only the ease of reading but also the depth of understanding.

This study aims to explore the effects of a high-contrast yellow-on-green color scheme compared to the traditional black-on-white text. By using eye-tracking data, we will assess whether the unconventional color scheme enhances or hinders reading comprehension and eye movement behavior. Additionally, subjective feedback from participants will provide insight into visual comfort and strain. Understanding these dynamics has implications for optimizing digital interfaces, particularly for diverse user populations with varying visual needs.

2 BACKGROUND

Eye-tracking technology has emerged as a critical tool in understanding cognitive processing and visual attention by providing objective metrics such as fixation duration, saccade amplitude, and regressions. These metrics have been widely used in human-computer interaction, psychology, and usability studies to evaluate how individuals interact with various stimuli, from digital interfaces to real-world environments. A key focus in recent years has been exploring the relationship between visual presentation and cognitive load, particularly in the context of reading comprehension.

High-contrast color schemes, such as yellow text on a green background, have been proposed as alternatives to conventional black-on-white text for certain user groups, including individuals with visual impairments or those in specific lighting conditions. However, the cognitive and perceptual impacts of these non-standard color schemes remain insufficiently understood. Previous research has highlighted that atypical color combinations can influence visual engagement, comprehension, and perceived visual comfort, but empirical evidence on these effects remains limited.

This study builds upon prior work by systematically investigating the effects of high-contrast color schemes on reading comprehension and eye movement behavior using eye-tracking technology. By analyzing key metrics such as fixations, revisits, and AOI (Area of Interest) view time, the study aims to elucidate how these color schemes impact cognitive processing and visual engagement. The findings have implications for the design of digital interfaces and accessibility tools, particularly for users with diverse visual and cognitive needs.

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3 EMPIRICAL VALIDATION

To evaluate the impact of color schemes on reading behavior, an empirical study was conducted comparing a standard black-on-white color scheme (base case) with a high-contrast green-on-pink color scheme (pink case). Eye-tracking technology was utilized to

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Figure 1: GP3 Gazepoint

collect objective metrics, including revisits, fixations, and average AOI (Area of Interest) view time, to assess visual engagement and cognitive processing under both conditions.

3.1 Experimental Design

The experiment consisted of two different procedures focusing on requiring the participants to read a brief passage. The passages were primarily differentiated by the font color and background color. Each participant was instructed to read the base-case passage comprised of black font on a white background followed by the altered case of neon green font color on a bright pink background. Afterwards, the participants were to answer two simple four question quizzes, one pertaining to each passage. The objective of the quiz was to compare the participants retention of the information to the fixation rates on the areas of interest placed in the background of the passage.

3.2 Participants

A total of seven participants were recruited via personal connections. All participants were male with ages ranging from 19 to 25 years. Five (71.43%) did not wear contacts or glasses, one (14.29%) wore glasses, and one (14.29%) wore contact lenses. None of the participants had any sort of severe medical visual impairment.

3.3 Procedure

Participants were informed about the consent process and asked to take a demographic survey prior to starting the procedure. The participants were also given a brief overview of the tasks they would be completing. Prior to starting the experiment setup, they were given an opportunity to ask any additional questions. If no further questions were asked, the participants were guided through the calibration process. Once the calibration process was successfully completed, the participants were shown a brief start screen and once they clicked start the base-case passage would appear. Once the user finished reading the first passage, the next passage comprised of brightly colored font and background was loaded. Similarly to the first passage, the participant would hit start and read the second passage. After the participants were finished reading both passages, they were given a short survey asking how difficult viewing and reading the passages were, and simple quiz questions about the material they had just read.

3.4 Apparatus

For this study, we used a Gaze Point 3 (GP3) desktop-mounted eye tracker to record eye movement behaviors. The GP3 has a sampling rate of 60 Hz and accuracy of 0.5-1 degrees. Participants were seated 60 cm away from a 23.8" desktop monitor with a resolution of 1920 x 1080. A wired keyboard and mouse were used to record detection and responses.

4 RESULTS

The experiment assessed user engagement through key eye-tracking metrics—revisits, fixations, and average AOI (Area of Interest) view time—under two conditions: the base case (black text on white background) and the pink case (green text on pink background). The results reveal distinct patterns across these metrics, reflecting the impact of visual presentation on reading behavior.

4.1 Revisits

In the base case, revisits were most frequent for User 10 (19 revisits) and User 11 (17 revisits), indicating heightened re-engagement with the text. Users 4 and 6 also demonstrated significant revisits, whereas User 7 exhibited the lowest revisit count (7 revisits), reflecting minimal backtracking.

For the pink case, User 3 exhibited the highest revisit count (9 revisits), closely followed by Users 4, 5, and 10, each with 8 revisits. User 11 had the lowest revisit count (3 revisits), suggesting decreased re-engagement under the pink case compared to the base case.

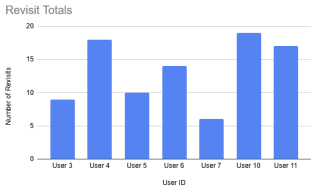

Figure 2: Base Case Total Revisits

4.2 Fixations

Fixation totals were highest in the base case for User 6 (22 fixations), followed by User 4 (21 fixations) and User 10 (20 fixations). User 3 had the lowest fixation count (12), indicating reduced visual attention to specific areas.

In the pink case, fixation totals were notably highest for User 3 (20 fixations), with moderate counts for Users 4 and 5 (16 fixations each). User 11 exhibited the fewest fixations (10), indicating decreased focus in the pink case relative to other users.

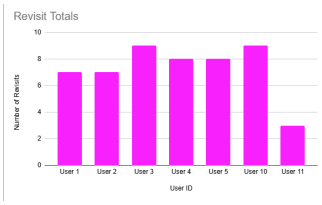

Figure 3: Pink Case Total Revisits

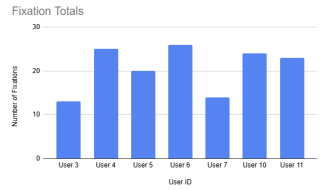

Figure 4: Base Case Total Fixations

4.3 Average AOI View Time

Average AOI view time in the base case was highest for User 11 (0.8 seconds), followed by User 6 (0.75 seconds) and User 4 (0.7 seconds), indicating prolonged engagement with specific areas of interest. User 7 recorded the lowest view time (0.4 seconds), suggesting less detailed attention.

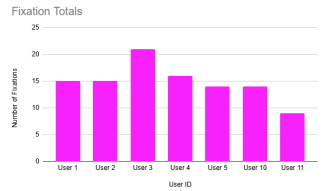

Figure 5: Pink Case Total Fixations

For the pink case, AOI view times mirrored trends in revisits and fixations, with User 3 demonstrating consistent engagement metrics. However, the reduced overall averages suggest that the pink case may have influenced the duration of visual processing negatively.

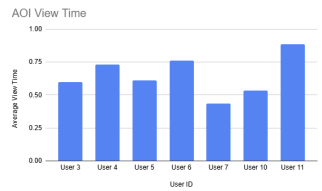

Figure 6: Base Case Average View Time

4.4 Summary

Across both cases, the base condition elicited higher overall engagement metrics, particularly for revisits and fixations. The pink case, while maintaining consistent engagement for some users, showed lower values across most metrics for others, particularly User 11. These results suggest that the non-standard pink color scheme may impose greater cognitive load or reduce visual comfort, potentially hindering reading comprehension and interaction.

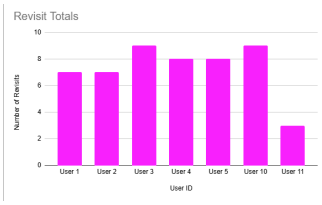

Figure 7: Pink Case Average View Time

5 DISCUSSION

The findings of this study provide valuable insights into the effects of color schemes on user engagement and visual behavior during reading tasks, as measured through eye-tracking metrics. By comparing a conventional base case (black text on a white background) with a high-contrast pink case (green text on a pink background), we observed notable differences in revisits, fixations, and AOI (Area of Interest) view time across users. These differences underscore the influence of visual presentation on cognitive load and reading behavior.

Revisits and Fixations In the base case, Users 10 and 11 exhibited the highest revisit counts and fixation totals, suggesting that the traditional black-on-white text facilitated detailed engagement with the text. The elevated metrics in these users may reflect more deliberate processing, consistent with previous studies highlighting the effectiveness of standard text-background combinations in reducing cognitive load. Conversely, User 7 demonstrated minimal revisits and fixations, indicative of a less thorough reading style or reduced interaction, possibly due to individual differences in reading strategies.

In the pink case, the revisit and fixation metrics showed a decline for certain users, particularly User 11, whose revisit and fixation counts were substantially lower than in the base case. This suggests that the high-contrast green-on-pink color scheme may have disrupted visual processing or increased visual discomfort, consistent with prior research on the adverse effects of non-standard color combinations on cognitive performance. However, User 3 displayed a notable increase in engagement metrics under the pink condition, which may indicate individual variability in adapting to unconventional visual presentations.

AOI View Time Average AOI view time followed similar trends, with the base case eliciting longer view durations for most users, particularly Users 6 and 11. The prolonged AOI view times in the base case suggest that the conventional color scheme supported sustained attention to areas of interest, aligning with expectations of reduced cognitive load and visual strain. In contrast, the pink case exhibited shorter AOI view times overall, suggesting that the non-standard color scheme may have impeded prolonged focus.

The substantial reduction in User 11's AOI view time further supports the hypothesis that high-contrast color schemes may increase cognitive load and reduce engagement.

Implications The results highlight the critical role of visual design in facilitating effective reading and comprehension. While high-contrast color schemes may be intended to improve accessibility for certain populations, their broader impact on cognitive load and visual engagement must be carefully considered. The findings suggest that non-standard color schemes, such as the pink case used in this study, may hinder reading performance for some users by increasing visual discomfort or cognitive processing demands. However, the observed variability in engagement metrics also underscores the need to account for individual differences in visual and cognitive processing when designing and evaluating digital interfaces.

Limitations and Future Work This study is limited by its small sample size, which may restrict the generalizability of the findings. Future research should explore the effects of high-contrast color schemes in larger and more diverse populations to capture a wider range of user behaviors. Additionally, examining other eye-tracking metrics, such as saccade amplitude and pupil dilation, could provide further insights into the cognitive mechanisms underlying these differences. Incorporating subjective measures of visual comfort and cognitive load would also complement the objective eye-tracking data, offering a more comprehensive understanding of user experiences.

In conclusion, the study reinforces the importance of optimizing visual design to balance accessibility and readability. The findings suggest that while unconventional color schemes may be suitable for specific contexts or users, their broader implications on reading performance warrant further investigation.

6 CONCLUSION

The analysis of user interaction metrics, including revisits, fixations, and AOI (Area of Interest) view time, reveals distinct behavioral patterns among participants. Users 10 and 11 demonstrated the highest levels of engagement, as indicated by their elevated revisit counts, fixation totals, and average AOI view times. These findings suggest a thorough and sustained interaction with key areas of interest. Conversely, User 7 consistently exhibited the lowest metrics across all measures, indicative of reduced engagement or more cursory interaction with the presented stimuli.

Users 4 and 6 also exhibited high fixation totals and average view times, suggesting focused attention, though their revisit counts varied, pointing to possible differences in task approach or cognitive processing strategies. User 3 displayed moderate levels across all metrics, reflecting balanced, yet less intensive interaction compared to the most engaged participants.

These results underscore the heterogeneity in user engagement behaviors and highlight the importance of considering individual variability when interpreting interaction data in eye-tracking studies. Such insights can inform the optimization of experimental design and user interface adjustments in future research.

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