

Exploring the Impact of environmental cues like Light and Music on Reading Experience: An Embodied Interaction Study

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ABSTRACT

In this embodied interaction study, we explore how integrating music and lighting effects into physical books influences reader engagement and emotional response. We selected ten passages from the book *Tuesdays with Morrie* by Mitch Albom and categorized them as “Sad” or “Not Sad” using Cohen’s Kappa for consistent categorization. Twelve participants read these passages under various lighting and music conditions to evaluate their impact on engagement, enjoyment, and immersion. Our findings indicate that both music and lighting significantly enhance the reading experience, with music having a particularly strong effect on sad passages. Younger readers and e-book enthusiasts responded more positively to interactive elements. Notably, most participants expressed interest in using interactive storytelling with sensory enhancements in the future, suggesting its potential for broader application. Despite the study’s limitations, such as a homogeneous sample and a focus on only music and lighting, it indicates that sensory enhancements can make reading more engaging and immersive. Future research should explore a wider range of sensory elements and a more diverse participant pool to refine interactive reading experiences further.

KEYWORDS

Interactive Reading, Environmental Cues, Music, Lighting, Reader Engagement, Emotional Resonance, Embodied Interaction, Book Format Preferences, Enjoyment

1 INTRODUCTION

In digital media and interactive experiences, the fusion of sensory elements such as light and music has gained significant attention for its potential to enhance user engagement and emotional resonance. This study explores an innovative approach to augmenting traditional book reading by integrating environmental cues—specifically, music and lighting effects—into physical books. Integrating these sensory elements into the reading experience represents a novel intersection of embodied interaction and narrative engagement. Traditional book reading has long been a solitary and immersive activity, but it often lacks the dynamic and immersive qualities found in more modern forms of media. With the advancement of technology and interactive design, there is an opportunity to transform this experience by incorporating environmental elements

that can influence readers’ emotional and cognitive responses. By embedding music and lighting effects within physical books, we aim to explore how these interactive components can enrich the reading experience, making it more immersive and emotionally engaging. The primary objective of this study is to investigate how adding music and lighting affects readers’ enjoyment, engagement, and immersion in the narrative. We seek to understand whether these sensory enhancements can create a more compelling reading experience and how they influence readers’ responses to different types of passages—whether they are emotionally charged or neutral. Additionally, the study examines the impact of these environmental cues across various demographic groups, including age, gender, and book format preference, to uncover nuanced insights into how different readers experience interactive storytelling. In this paper, we present a comprehensive analysis of the collected data, exploring how music and lighting interact with the reading process and influence participants’ perceptions of their reading experience. By employing descriptive and inferential statistics, along with visualizations such as heat-maps, bar charts, and box plots, we aim to provide a detailed understanding of the impact of these sensory elements. Our findings will contribute to the growing body of research on embodied interaction and offer practical insights for future developments in interactive media and reading experiences.

2 BACKGROUND

The integration of environmental cues such as lighting and music into reading experiences has garnered considerable interest in recent years, intersecting multiple fields including cognitive psychology, multimedia studies, and interactive design. Existing research underscores the significant impact that sensory elements can have on cognitive and emotional processes during reading. Studies on lighting reveal its profound influence on reading comfort and performance. Knez (1995) found that different lighting conditions can significantly affect mood and perception, which is crucial for creating immersive reading environments. Boyce et al. (2003) further emphasized that appropriate lighting design enhances visual comfort and performance during reading tasks, suggesting that lighting is a key factor in optimizing reading experiences [1] [4]. The role of music in cognitive and emotional processes has also been extensively explored. Research by Thompson, Schellenberg, and Husain (2001) indicates that background music can enhance mood and engagement, potentially affecting interactive storytelling

experiences. Husain, Thompson, and Schellenberg (2002) demonstrated that music can modulate emotional responses and cognitive functions, suggesting that well-chosen musical elements could enrich the emotional resonance of narratives [8] [3]. The concept of multi-sensory integration, where various sensory modalities are combined to enhance user experiences, is well-established in interactive media studies. Spence and Shama (2010) reviewed how multi-sensory stimuli, including visual and auditory elements, contribute to more immersive and engaging experiences. This supports the notion that integrating lighting and music with text can create a more compelling reading experience [7]. Embodied interaction, which focuses on how physical and sensory experiences shape user interactions, is an emerging area of research. Dourish (2001) introduced the concept of embodied interaction in human-computer interaction, highlighting the importance of sensory experiences in shaping user engagement. More recent studies, such as those by Koskinen et al. (2011), have explored how embodied interaction can be applied to multimedia and interactive storytelling, suggesting that sensory cues can enhance narrative engagement [2] [5]. Personalized reading environments, tailored to individual preferences, have been the subject of recent investigations. McDonald and Al-Mosawe (2019) explored how personalized lighting and auditory environments impact reading and learning outcomes. Their findings indicate that aligning environmental cues with individual preferences can enhance engagement and comprehension, which aligns with the concept of optimizing sensory elements to improve reading experiences [6]. Overall, the current state of research highlights the significant role that environmental cues, such as lighting and music, play in shaping cognitive and emotional responses. By integrating these elements into interactive reading experiences, there is potential to create more immersive and engaging narratives. This study builds on these findings by exploring how personalized lighting and music can enhance reader engagement, enjoyment, and immersion, paving the way for future innovations in interactive storytelling.

3 METHODOLOGY

We initiated our research by carefully selecting passages from the book "Tuesdays with Morrie" by Mitch Albom, a text rich in emotional depth, which provided an ideal setting for examining the influence of environmental stimuli on reading. We randomly chose ten passages and classified each as either "Sad" or "Not Sad" based on our collective interpretation of their emotional tone. In instances where our initial categorizations were tied, we opted to replace the passage to maintain a clear consensus. To validate the reliability of our categorizations, we utilized Cohen's Kappa, a statistical measure that evaluates the agreement between raters beyond chance agreement. Next, we had 12 participants read the passages under different lighting and music conditions. This part of the study was set up to see how these environmental factors affected their emotions and overall reading experience. Our goal was to carefully explore how these elements of embodied interaction could make the reading experience more engaging.

3.1 Cohen's Kappa for Inter-Rater Reliability

To ensure the reliability of our passage categorization, we turned to Cohen's Kappa (κ), a statistical measure designed to evaluate

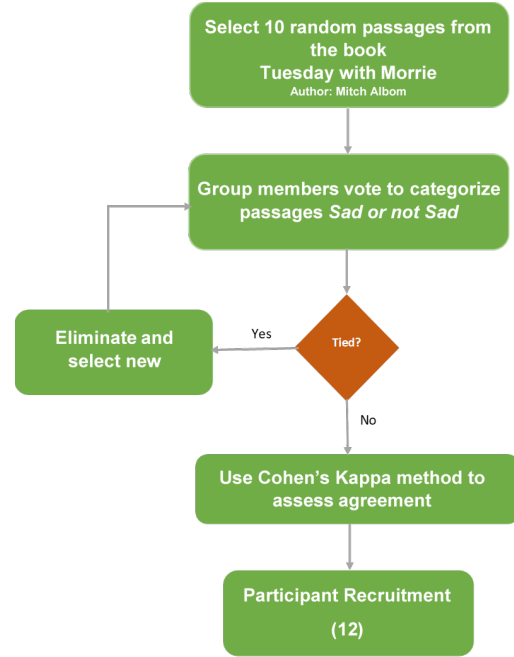


Figure 1: Passage Selection and Categorization Process for the Study

the agreement between raters while considering the possibility of chance agreement. This was particularly relevant for our study, where we needed to classify passages from the book *Tuesdays with Morrie* by Mitch Albom as either 'sad' or 'not sad.' We selected ten passages at random and had our team members vote on their emotional classification. In cases of a tie, we replaced the passage to maintain a clear consensus. Cohen's Kappa is calculated using the following formula:

$$\kappa = \frac{P_0 - P_e}{1 - P_e} \quad (1)$$

Here, P_0 represents the observed agreement—the actual level of agreement we achieved—while P_e is the expected agreement by chance, based on the distribution of our categorizations. The resulting Kappa value indicates the degree of consistency in our categorization. A Kappa of 1 means perfect agreement, 0 suggests agreement no better than chance, and negative values imply agreement worse than chance. To calculate P_0 , we simply counted the

Handwritten calculation on grid paper:

$$\begin{aligned} \text{Average } \kappa &= \frac{0.8 + 0.58 + 0.61 + 0.8 + 0.8 + 0.61}{6} \\ &= 0.7 \\ &= \text{Good} \end{aligned}$$

Figure 2: Cohen's Kappa K for our passages

passages where our raters agreed and divided by the total number of passages. For P_e , we looked at the distribution of our categorizations. In our study, the average Cohen's Kappa value was 0.7, indicating a substantial level of agreement and confirming the robustness of our categorization process.

3.2 Pilot Test

We conducted a pilot test within our research team to validate the experimental design, procedure, and environmental setup. This preliminary phase enabled us to personally experience the reading environment and identify any potential issues that could influence the participants. During this test, we read the passages under a range of lighting and musical conditions, observing the shifts in emotional tones and the impact of environmental alterations on our reading experiences. Based on these observations, we implemented several refinements to enhance the study's flow, such as adjusting the timing of music and lighting transitions to ensure they were seamless and non-intrusive.

3.3 Study Design and Conditions

Following the meticulous categorization of passages into "Sad" and "Not Sad," we designed a controlled experiment to assess the influence of environmental cues on the reading experience of participants. We created a dedicated reading environment that allowed for precise manipulation of lighting and music to match the emotional tone of each passage. For "Sad" passages, we used a dim blue light to create a somber atmosphere. Conversely, for "Not Sad" passages, we employed a warm, bright tone light to evoke a more neutral or positive ambiance. Complementing the lighting, we carefully selected

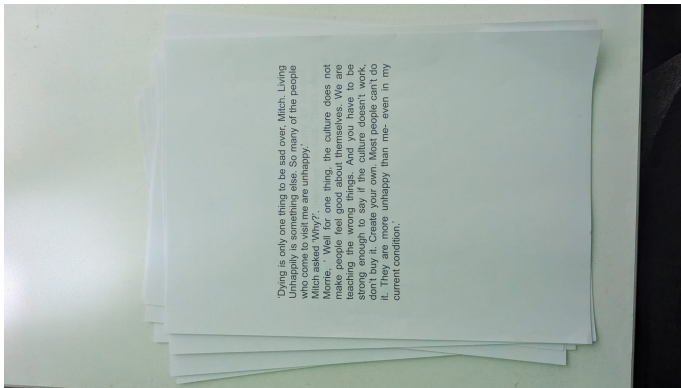


Figure 3: Passages printed for the Reading experiment

background music that harmonized with the emotional content of the passages. Melancholic tracks with a slow tempo were played during the reading of "Sad" passages, while neutral or upbeat music was chosen for "Not Sad" passages. These environmental conditions were deliberately crafted to amplify the emotional impact of the reading material and to provide a rich context for evaluating the effect of sensory stimuli on the reading experience. To maintain consistency throughout the experiment, all readings occurred in the same room, at the same time of day, and under controlled temperature conditions. This controlled environment ensured that external



Figure 4: Environmental Setup for Reading Experiment.

factors did not confound the study's results, allowing us to focus on the impact of lighting and music on the reading experience.

3.4 Participant Recruitment and Study Procedure

We recruited 12 participants for our study to include a range of backgrounds in terms of age, gender, and reading habits. However, the age diversity in our sample was limited. Most participants were between 25 and 34 years old, with fewer participants in the 18-24 and 35-45 age groups. This limited age range may influence how well our findings apply to different age groups, as the effect of environmental cues on reading experiences might differ across ages. Despite this limitation, we collected demographic information and data on reading preferences and habits through a pre-experiment survey. This survey provided valuable context that we used to account for individual differences in our analysis. During the ex-

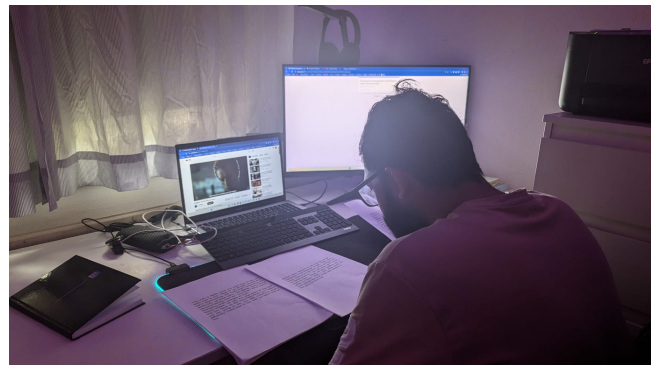


Figure 5: Participant reading

periment, participants read a series of five "Sad" and five "Not Sad"

passages in random order. For each passage, the corresponding lighting and music settings were applied to enhance the emotional tone. After reading each passage, participants rated their experience on a 5-point Likert scale, responding to questions about enjoyment, engagement, and immersion. Additional questions asked how well the music and lighting enhanced their emotional response to each passage and whether they found the environmental changes distracting. These responses provided the core quantitative data for the study.

3.5 Ethical Consideration

We ensured that all participants provided informed consent before participating in the study. The consent process informed participants of the study's objectives and assured them that their data would be anonymized. Participants were also given the option to withdraw from the study at any time without consequence. This process ensured that our research adhered to ethical standards and protected participants' privacy throughout the study.

3.6 Data Collection and Analysis

After the reading task, participants completed a post-experiment survey where they provided additional feedback on their experience with the interactive storytelling system. We collected both quantitative ratings and qualitative comments, which gave us a comprehensive dataset for analysis. Data were gathered through Google Forms and automatically transferred to a spreadsheet for further processing. For analysis, we used Pearson correlations to explore relationships between participants' enjoyment, engagement, and immersion and the environmental stimuli of lighting and music. We also conducted a comparative analysis to assess the differential effects of lighting and music on "Sad" versus "Not Sad" passages. This allowed us to determine whether the environmental stimuli had a significant impact on participants' emotional responses and overall reading experience.

4 RESULT

In the results section, we present and analyze the key findings from our study. We start with an overview of the data we collected, which includes variables related to enjoyment, engagement, and immersion, as well as the demographics of our participants. Descriptive statistics provide a clear picture of our sample and their responses, setting the stage for further analysis. Next, we focus on how environmental factors—lighting and music—affect participants' enjoyment, engagement, and immersion. We examine how enjoyment varies across different demographic groups, such as age, gender, and preference for book format (physical books versus e-books). We also explore how these sensory elements influenced the reading experience. Engagement is analyzed through participants' feedback on how music and lighting worked together in different passages, while immersion is assessed based on how well these elements made the reading experience more engaging. We use correlation analysis to look at the relationships between enjoyment, engagement, and immersion, and present these findings with visual aids like heatmaps to highlight important correlations and interactions. We also compare responses from different demographic groups to see how factors like age and book format preference

affected their reactions to environmental cues. This includes examining how different groups experienced interactive storytelling and how lighting and music impacted their overall reading experience. Additionally, we explore participants' interest in using interactive storytelling with sensory elements in the future. We analyze the connection between their enjoyment and engagement and their willingness to continue using these methods in their regular reading. Throughout the section, we use visual tools such as bar charts, box plots, and heatmaps to make our key findings clear. Each visual is accompanied by an explanation that ties the data back to the study's main goals. In the final part of the results section, we summarize our findings and emphasize how personalized environmental cues can enhance the reading experience. We discuss the importance of customizing sensory elements to individual preferences to boost engagement and immersion and suggest directions for future research on optimizing lighting and music for reader satisfaction.

4.1 Pre-study Questionnaire

The pre-study questionnaire gathered detailed information about participants' reading habits, preferences, and environmental conditions such as the use of music while reading. The data provides insights into the demographics and reading behaviors of the participants, which can help to contextualize their responses in the subsequent reading experiments. Most participants fell within the

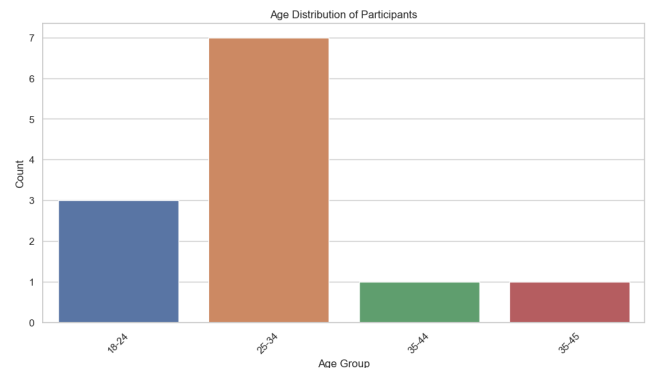


Figure 6: Age group Distribution of the Participants

25-34 age range, with a smaller group from the 18-24 and 35-45 age groups. The gender distribution was predominantly male, and most participants had a Master's degree, indicating a highly educated sample. Regarding reading frequency, responses varied, with some participants reading once a week or a few times a week, while others indicated they rarely or never read. This diversity in reading frequency may influence how participants engage with the reading experiment, particularly in how comfortable or immersed they felt during the interactive storytelling experience. Mystery/Thriller books were the most commonly read genre, with others opting for Fantasy/Science Fiction, Science/Technology, and Non-fiction. This variety in genre preferences may reflect differences in emotional engagement during the reading experiment. Participants showed a strong preference for physical books, though some indicated a preference for e-books or no preference. This distinction is important as

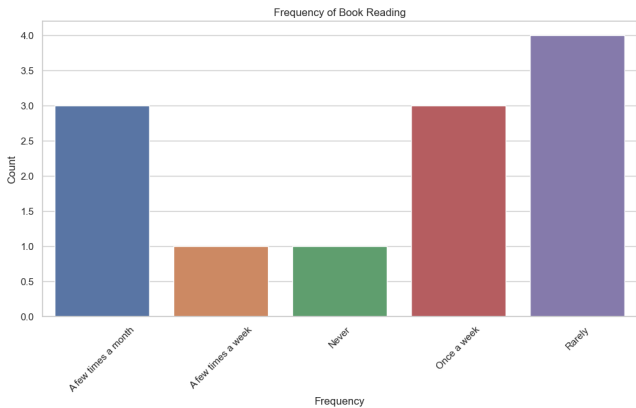


Figure 7: Reading Habit(Frequency)

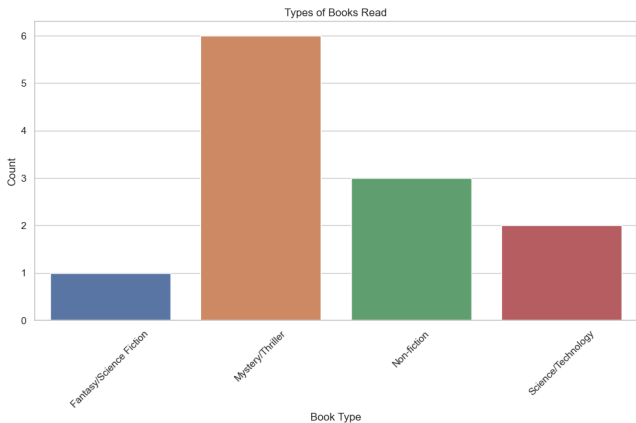


Figure 8: Participants' Most Frequently Read Book Genres

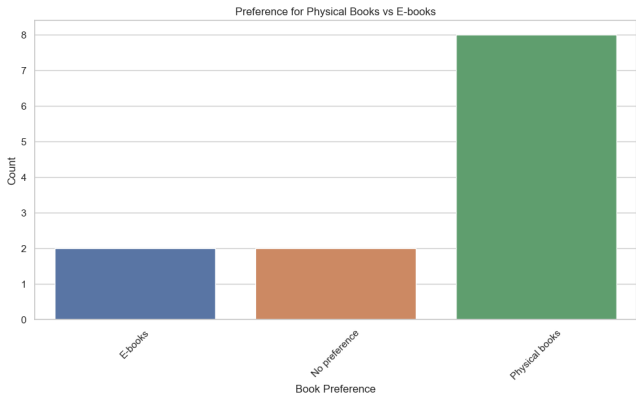


Figure 9: Book Format Preference

it may correlate with how these individuals responded to the integration of lighting and music in the experiment. Most participants preferred to read in the evening or at night, with some favoring the afternoon. The environmental conditions in which individuals

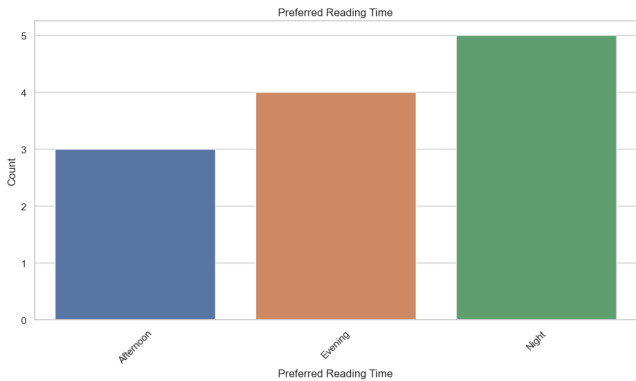


Figure 10: Preferred reading time

typically read may influence how they experienced the lighting changes in the experiment, as their usual reading times may align with different lighting preferences. Interestingly, a majority of par-

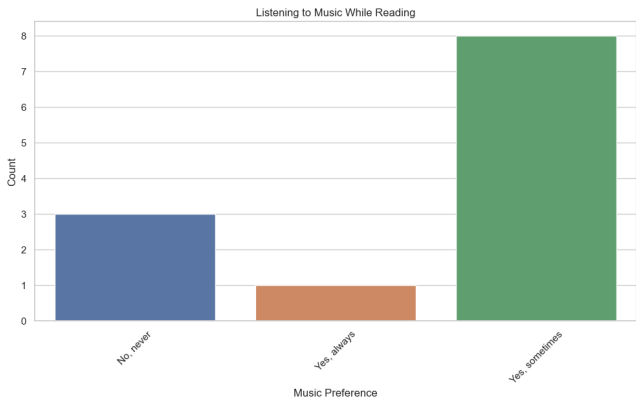


Figure 11: Listening to Music while reading

ticipants reported occasionally listening to music while reading, with answers ranging from "yes, sometimes" to "yes, always." A few participants indicated that they never listen to music while reading. These distinctions in habitual music-listening behaviors suggest that participants might respond differently to the music incorporated into the experiment, with some possibly being more accustomed to it than others. the pre-study questionnaire revealed a diverse set of reading habits, preferences, and demographic factors, all of which are likely to have influenced the participants' engagement with the interactive storytelling experience. Understanding these baseline behaviors helps contextualize the impact of environmental cues like lighting and music on their subsequent enjoyment, engagement, and immersion during the study.

4.2 Correlation Result

The correlation matrix is a key tool in our analysis, offering a quantitative view of the relationships between various factors influencing the reading experience. The diagonal elements of the matrix show a perfect correlation of 1, reflecting the self-correlation of each

variable. A notable finding is the negative correlation of -0.52 between *Enjoyment* and *Lighting Enhancement Sad*, indicating that participants tended to enjoy sad passages less when the lighting was enhanced to match the somber tone. Conversely, *Enjoyment* is positively correlated with *Lighting Enhancement Not Sad* at 0.49 , suggesting that improved lighting for non-sad passages can enhance enjoyment. *Engagement* shows a positive correlation with *Music Enhancement Not Sad* at 0.32 , implying that better music for non-sad passages can increase engagement. However, it exhibits a slight negative correlation with *Lighting Enhancement Sad* at -0.098 , which might suggest that sad lighting could potentially reduce engagement.

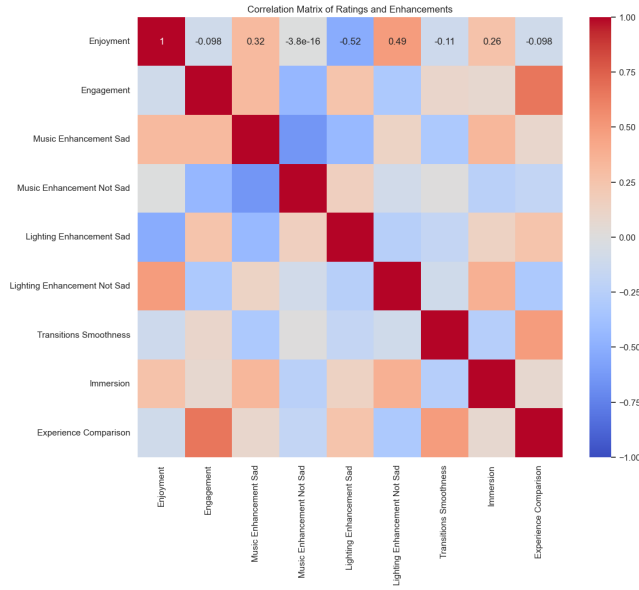


Figure 12: Correlation Matrix of Key Variables

The variable *Music Enhancement Sad* shows negative correlations with several other variables, including *Lighting Enhancement Not Sad* and *Experience Comparison*. This indicates that as the music for sad passages improves, these other factors tend to decline, possibly due to the music overshadowing or conflicting with other sensory enhancements. *Music Enhancement Not Sad* has a strong negative correlation with *Lighting Enhancement Sad* at -0.74 , suggesting that enhancements for non-sad content are often inversely related to those for sad content. This is likely because the enhancements are designed to create distinct user experiences for different emotional tones. *Immersion* exhibits weak correlations with most variables, indicating it is not strongly influenced by other enhancements. Both *Transitions Smoothness* and *Experience Comparison* have negative correlations with various variables, which might imply that smoother transitions and experience comparisons are inversely related to some enhancements. Overall, the matrix highlights potential conflicts between enhancements for *Sad* and *Not Sad* content, emphasizing the importance of context when selecting and applying enhancements to optimize the user experience effectively. These findings underscore the need for personalized environmental

cues tailored to individual preferences and the emotional tone of the reading material.

4.3 Post-study Questionnaire

Following the study, we analyzed the post-experiment data to assess how environmental cues, such as light and music, affected the reading experience, focusing on enjoyment, engagement, and immersion. We also considered participant feedback to understand the impact of demographic factors, such as age and book format preferences, on their responses. This analysis provides insights into how personalized environmental cues can enhance an interactive and immersive reading experience. The key results and their implications for future research are discussed below. Participant feedback revealed several points of interest:

Distraction from Environmental Cues: For sad passages, some participants found the combination of music and lighting to be distracting. Specifically, the music was sometimes reported as a distraction, suggesting that sensory elements might need better calibration to avoid interfering with the reading experience.

Suggestions for Improvement: Participants mentioned that the lighting could be improved to enhance the overall experience. This feedback indicates that adjustments in lighting might be necessary to better align with the emotional tone of the passages and improve user satisfaction.

The results from the post-experiment data are illustrated in the following figures:

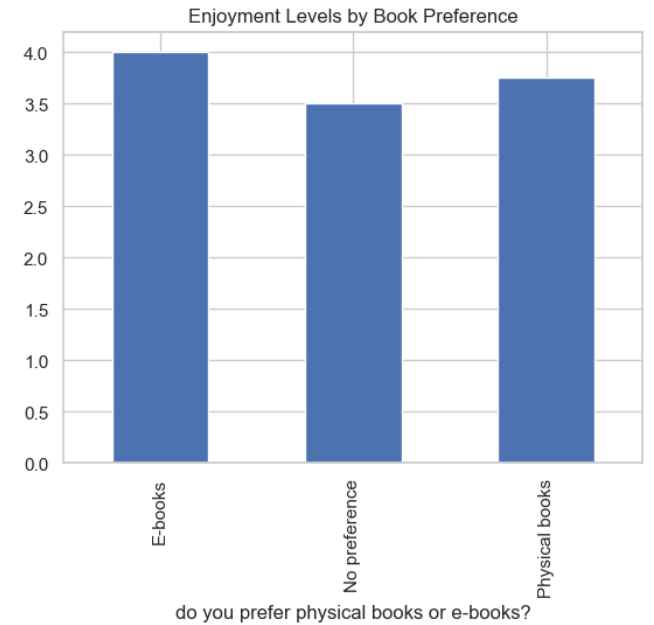


Figure 13: Enjoyment Level by Book Format Preference

Figure 13 shows enjoyment levels across participants with different book format preferences: e-books, physical books, and no preference. Participants who preferred e-books reported the highest average enjoyment score, nearly 4 out of 5. Those who preferred physical books also had high enjoyment ratings, though slightly

lower than e-books. Participants with no strong preference experienced lower enjoyment. This suggests that environmental factors such as lighting and music might have had a greater positive influence on e-book readers, possibly due to their familiarity with adaptable environmental conditions like dimmable screens and background music. Those with no specific preference may be less sensitive to these cues, explaining their lower enjoyment scores.

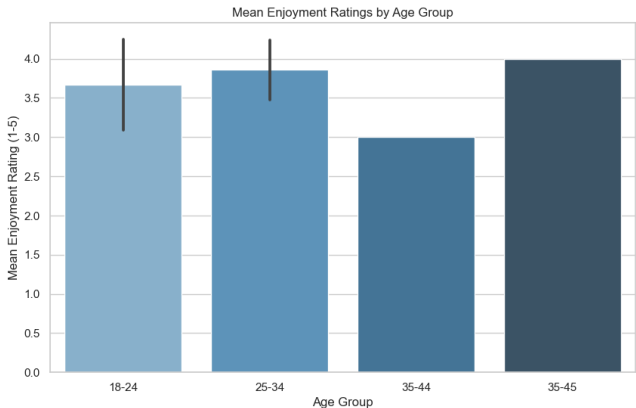


Figure 14: Enjoyment Ratings by Age Group

Figure 14 illustrates mean enjoyment ratings by age group: 18-24, 25-34, 35-44, and 35-45. The 35-45 age group had the highest average enjoyment rating, close to 4, followed by the 25-34 group with a mean rating of around 3.7. Participants aged 18-24 reported high enjoyment, slightly below the 25-34 group. The 35-44 group had the lowest mean enjoyment score. These differences suggest that environmental factors like lighting and music may affect readers differently based on age. Older participants, especially those in the 35-45 group, might benefit more from calm and consistent stimuli, enhancing their reading experience, while younger participants may respond better to dynamic cues. Figure 15 provides a visual representation of participants' enjoyment levels when exposed to music and lighting while reading passages categorized as *Sad* and *Not Sad*. For the *Sad* passages, music had a pronounced effect, with 81.7% of participants indicating higher enjoyment when music was present. In contrast, the impact of lighting was less pronounced, with 61.7% of participants reporting increased enjoyment of the lighting enhancement. This suggests that music plays a more significant role in enhancing the reading experience, particularly for emotionally charged content. For the *Not Sad* passages, music continued to demonstrate a positive influence, with 73.3% of participants experiencing heightened enjoyment. Lighting also had a notable effect, with 68.3% of participants reporting increased enjoyment when the lighting was adjusted to complement the neutral or upbeat tone of the passages. This indicates that while both music and lighting can enhance the reading experience, music tends to have a more substantial impact across different emotional tones in the narrative. Figure 16 shows participants' interest in using interactive storytelling in the future. Most participants expressed strong interest, with nine choosing "Yes," and three showing moderate interest with "Maybe." This high level of interest suggests that the sensory cues

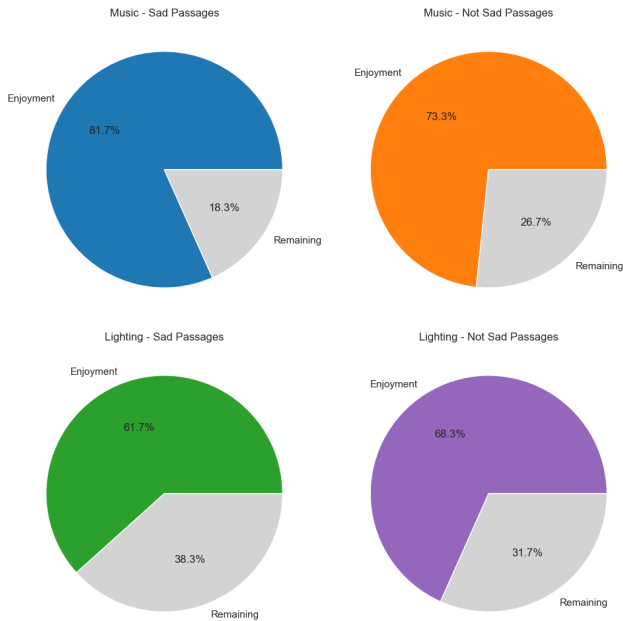


Figure 15: Enjoyment Levels with Music and Lighting during Sad and Not Sad Passages

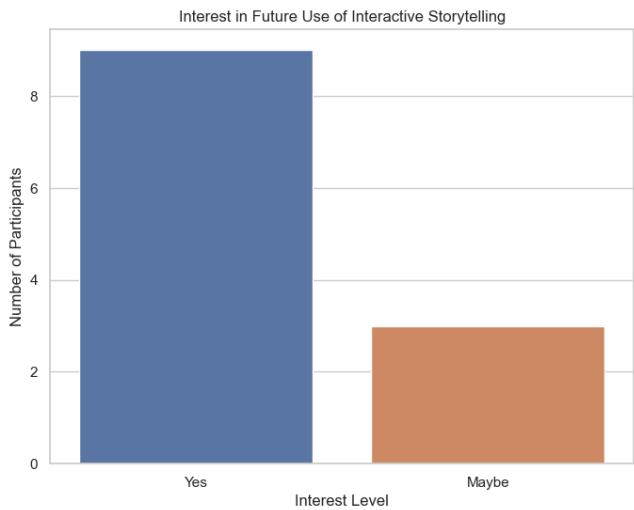


Figure 16: Interest in Future Use of Interactive Storytelling

used in the study—such as lighting and music—positively influenced participants' engagement with the reading material. This form of interactive storytelling is well-received, indicating potential for further exploration and application in future reading experiences.

4.4 Discussion

Our study reveals that environmental cues, such as music and lighting, significantly impact the reading experience by enhancing enjoyment, engagement, and immersion. Participant feedback

highlighted two main points: some found the combination of music and lighting distracting during *Sad* passages, and there were suggestions for improving lighting to better match the emotional tone of the passages. Analysis of the data showed that e-book readers reported higher enjoyment compared to physical book readers, likely due to the customizable nature of digital formats. Participants with no strong format preference experienced lower enjoyment, indicating that personalized sensory elements are more effective for those with specific format preferences. Age-related differences in enjoyment were also evident. The 35-45 age group reported the highest enjoyment, suggesting that older readers may prefer calmer sensory experiences, while younger readers might respond better to more dynamic cues. Music had a more pronounced effect on enjoyment for both *Sad* and *Not Sad* passages, indicating its significant role in enhancing the reading experience across emotional tones. Lighting also improved enjoyment but to a lesser extent. The high level of interest in future use of interactive storytelling suggests that readers are open to incorporating dynamic sensory elements into their reading experience. This interest aligns with a trend toward more immersive reading practices and highlights the potential for further research into personalized, interactive reading environments.

4.5 Limitations and Future Scope

This study, while providing valuable insights into the impact of environmental cues on the reading experience, has several limitations that must be acknowledged. The participant sample was predominantly composed of individuals aged 25-34, male, and with a high level of education. This homogeneity may not fully represent the broader population's responses to sensory enhancements in reading environments. Additionally, the study focused exclusively on the sensory elements of music and lighting, omitting other potential factors such as scent or temperature. Variations between participants' habitual reading conditions and the experimental setup could also influence the results. The reliance on self-reported data may introduce response bias, and incorporating objective measures could enhance the accuracy of findings. Future research should aim to address these limitations by recruiting a more diverse participant pool to improve the generalizability of the results. Exploring additional sensory elements, such as scent and temperature, would provide a more comprehensive understanding of multi-sensory impacts on reading. Investigating the long-term effects of sensory enhancements and the potential of adaptive technologies that personalize sensory experiences based on real-time feedback could further enhance interactive storytelling. Finally, applying these interactive approaches in educational or therapeutic contexts may reveal additional benefits and applications, broadening the scope of interactive reading experiences.

5 CONCLUSION

Our study demonstrates that environmental cues, such as music and lighting, significantly enhance the reading experience by increasing enjoyment, engagement, and immersion. Participants noted that while these cues generally improved their experience, some found the combination of music and lighting distracting during *Sad* passages, leading to suggestions for better alignment of lighting with

the emotional tone of the text. Analysis revealed that e-book readers reported higher enjoyment than physical book readers, likely due to the customizable features of digital formats. Participants with no strong format preference experienced lower enjoyment, highlighting the effectiveness of personalized sensory elements. Age-related differences were also evident, with the 35-45 age group reporting the highest enjoyment levels. Music had a more pronounced impact on enjoyment, especially with *Sad* passages, while lighting also contributed positively but to a lesser extent. The strong interest in the future use of interactive storytelling suggests that readers are receptive to incorporating dynamic sensory elements into their reading experiences. This underscores the potential for further research into personalized and adaptive reading environments.

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