

Optimization Strategy of VR Exhibition Hall Design based on Eye Tracking Technology

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Abstract: By quantitatively analyzing a group of college students' exhibition visual behaviors in a VR environment, the study found that storytelling and visual design had a significant effect on attracting students' attention. The experimental data supports the importance of personalized learning experience and highlights the role of exhibition layout and navigation optimization in enhancing students' visiting experience. The results show that VR exhibition design incorporating eye-tracking technology can effectively enhance the educational effect and provide valuable guidance for the design optimization of future VR exhibition halls.

Keywords: Eye Tracking; Virtual Reality; Educational Exhibition; Tobii VR.

1. Introduction

With the continuous progress of science and technology, the application of virtual reality (VR) technology in the field of education has become more and more widespread, through which the learning experience of students can be significantly improved and the teaching effect can be enhanced. VR technology creates immersive learning environments, which facilitates students to deepen their understanding and memorization of knowledge through innovative learning experiences and interactions. As a kind of digitized exhibition space that provides learners with an immersive learning platform by recreating real-world teaching scenes, historical events, and scientific experiments. Learners can be exposed to rich educational topics in these VR exhibition halls for a more intuitive learning experience.

Eye tracking technology, as a commonly used research tool in the fields of cognitive psychology, human-computer interaction and visual perception, through in-depth analysis of the user's eye-movement data, researchers can reveal information such as the user's attention allocation, interest focus point and cognitive load, which in turn can help teachers to accurately optimize the design of teaching content. Although it has been shown that VR technology can provide a rich immersive learning experience and stimulate students' interest in learning, the understanding of how the display content in VR exhibition halls affects the distribution of students' attention is still limited, and further in-depth exploration is needed.

2. Experimental Design

(1) Experimental Objectives

The study aims to quantitatively analyze students' visual behaviors in the VR exhibition hall using eye-tracking technology, such as focusing on key indicators such as gaze duration and number of gazes. Through in-depth analysis of participants' eye movement patterns while observing the exhibition hall in commemoration of Chairman Mao's birth, the study reveals the individual's allocation of attention to different exhibition contents and their visual attention characteristics, so as to provide empirical support for innovative VR exhibition hall content design.

(2) Experimental environment

The experimental environment is set in a quiet laboratory with uniform and sufficient light conditions. The eye-tracker used in the experimental equipment was calibrated to ensure the accuracy and reliability of the data.

(3) Subjects

Ten college students between the ages of 18 and 22 were openly recruited as participants in the experiment, and all participants signed an informed consent form after understanding the experimental procedure in detail. In order to guarantee the data quality, participants were screened for visual acuity, and visual impairments that might affect the accuracy of eye movement data were excluded.

(4) Experimental tools

The study used the Tobii VR eye-tracker with Tobii Pro Lab version 1.162B software. The Tobii VR eye-tracker is a device that integrates high-precision eye-tracking technology and a virtual reality environment, which captures the user's eye movement data in real time and provides an immersive visual experience. The Tobii Pro Lab version 1.162B software is a professional eye movement data analysis tool, which is used in conjunction with hardware such as the Tobii VR eye tracker to provide powerful data processing, visualization and statistical analysis functions.

(5) Experimental materials

In order to assess the effects of different content complexity on visual attention, the study selected 12 sets of VR scenes from the Exhibition Hall in Commemoration of Chairman Mao's Birthday (Flag Flying Productions) from the 720 Cloud platform. These scenes covered diverse historical footage and exhibition elements, and facilitated participants' visual exploration by providing rich visual information.

(6) Experimental Procedure

Before the start of the experiment, the principal investigator guided the participants to the experimental area and explained in detail the objectives, steps and requirements of the experiment. To ensure that the eye-tracker could accurately track the subjects' eye movements and collect high-quality eye-movement data, participants wore and calibrated the eye-tracker under the guidance of the instructor. When ready, participants viewed 12 sets of VR scenes, each with a viewing duration of 20 seconds, which was long enough for subjects to fully visually explore the content while

avoiding visual fatigue. After data collection, the eye movement data were analyzed in detail using the Analyze module of the Tobii Pro Lab software, including the generation of hotspot and trajectory maps.

3. Experimental Data Analysis

In this study, data were collected through eye-tracking technology and descriptive statistical analysis was applied to assess the effects of different content designs of the VR exhibition hall on the distribution of students' visual attention. Through statistical methods such as analysis of variance (ANOVA), we not only quantified students' visual behaviors while viewing different exhibition contents, but also explored

the significant differences between these behaviors and their potential significance in the field of education.

(1) Descriptive statistical analysis

First, descriptive statistical analyses were conducted on five visual indicators, including Total_duration_of_fixations, Average_duration_of_fixations, Number_of_fixations, Total_duration_of_Visit (total duration of visit) and Number_of_saccades_in_AOI (number of sweeps in the area of interest), which can comprehensively reflect the distribution of students' visual attention and eye movement patterns when viewing VR exhibitions, and each of these metrics is given with the sample size, minimum, maximum, mean, standard deviation, and median (see Table 1).

Table 1. Basic indicators

Name	Sample size	Minimum	Maximum	average value	standard deviation	Media
Total duration of fixations	120	3901.000	17852.000	13780.067	2494.928	14128.000
Average duration of fixations	120	144.000	789.000	244.383	74.414	229.500
Number of fixations	120	22.000	77.000	58.042	9.670	59.000
Total duration of Visit	120	18021.000	20024.000	19871.483	265.752	19981.500
Number of saccades in AOI	120	4.000	64.000	38.242	11.821	40.000

Descriptive analysis describes the overall picture of the data through mean or median, based on the data in the table above, we can draw the following conclusions:

1) individual variability in visual attention data

The maximum value of Average_duration_of_fixations exceeds the mean by 3 standard deviations, a phenomenon that points to the existence of significant individual differences in visual attention data. This variability may arise from a variety of factors, such as an individual's cognitive ability, attention span, emotional state, and fatigue level. This variability suggests that individuals may adopt different strategies and processes when processing visual information. For example, some individuals may be more inclined to process visual information in depth, resulting in longer gaze times, while others may rely more on rapid visual scanning with short gaze times. Therefore, when designing visual tasks and assessing attention in VR exhibitions, the diversity of individuals needs to be taken into account, and appropriate statistical methods need to be adopted to accurately describe and interpret the data.

2) Concentration trend of the number of fixations and visit duration of the sample

The concentration trends of Number_of_fixations and Total_duration_of_Visit indicate that most participants have a more consistent distribution of attention in these areas, which reflects the common cognitive patterns and behavioral strategies of the participants in performing visual tasks. For example, participants may commonly adopt similar visual search strategies or show similar allocation of attention when confronted with visual stimuli. This consistency reveals some universal cognitive mechanisms in humans when processing visual information, such as selective focusing of attention and maintenance of visual memory. Understanding these concentration trends is important in terms of optimizing the design of VR pavilion content and evaluating the effectiveness of visual interventions.

3) Overall volatility of data

The standard deviations of most of the indicators are close to or less than the mean, which indicates that the data are relatively stable overall with little volatility. This stability implies a certain degree of predictability and consistency in

participants' visual attention performance under the given task and experimental conditions. Lower volatility facilitates more accurate assessment and comparison of attentional performance across participants or conditions, while also requiring vigilance against potential factors that could lead to increased volatility, such as changes in experimental conditions, fluctuations in participant status, or measurement error. For more volatile metrics, it is more appropriate to use the median as an indicator of descriptive statistics because it better represents the specifics of the majority of the sample.

(2) Analysis of Variance (ANOVA)

To further explore the effects of different exhibition designs on students' visual attention, analysis of variance (ANOVA) was applied. By setting the grouping variable {Media} and variable Y (the five basic indicators in Table 1), the significant differences in visual behavior among different exhibition designs were tested. The analysis process included normality test, ANOVA chi-square test, and assessment of significance.

The analysis process mainly includes: 1) group quantitative variables (Y) according to the fixed category variables (X), test their normality test to see whether the overall distribution of the data shows a normal distribution, if the test fails, go to the algorithm selection page to select [normality test] for further analysis. 2) Group the quantitative variables (Y) according to the qualitative variables (X) and perform the ANOVA test to see if the P value is less than 0.05. If the P value is greater than 0.05, use ANOVA to see if the P value is significant (P<0.05). 3) If significance is presented, the difference can be analyzed based on the mean ± standard deviation, and vice versa indicates that no difference is presented. 4) If the one-way ANOVA shows significance, the differences can also be analyzed quantitatively with the help of quantitative analysis of effects.

The results showed that there was a significant difference between different exhibition designs in the indicator of total gaze duration (F=2.232, p=0.018), and post hoc multiple comparisons analyses revealed which specific exhibition designs were significantly different from each other. For example, the exhibition designs of “Chairman Mao in Xibaipo” and “Aerospace Spirit” attracted students more than the “Entrance” and “Foreword” sections. The exhibition

design of “Chairman Mao in Xibaipo” and “Aerospace Spirit” attracted students' attention for a longer period of time than the “Entrance” and “Foreword” sections. This is because the exhibition design of “Chairman Mao in Xibaipo” and “Aerospace Spirit” contains more information related to historical figures and major events, which is more attractive to students and has more educational significance.

(3) Attention density distribution analysis

The hotspot map generated by Tobii Pro Lab software visualizes the distribution of participants' visual attention points in the VR exhibition. The color gradient indicates the density of attention, and the darker the color area indicates that more visual attention is focused on it. In the hotspot map of “Spirit of Spaceflight” (see Figure 1), it can be observed that certain regions are particularly dark, which indicates that these regions attracted more visual attention from the subjects. These high-density attention areas are related to the educational content and design elements of the exhibition, for example, the exhibit may have used striking images, prominent text or interactive elements, etc., which generated more interest for the subjects. In contrast, the hotspot map of the “entrance” scene showed a lower attention density (see Figure 2), implying that the content in the entrance area was presented in a more conventional way or lacked sufficient visual stimuli to attract the attention of the subjects as in the other exhibition areas. By comparing the hotspot maps of different exhibition areas, it can be found that areas with rich content and storytelling elements in the exhibition design are more likely to attract students' attention.



Fig 1. “Spirit of Spaceflight” hotspot map



Fig 2. “Entrance to the exhibition hall” hotspot map

(4) Analysis of Attention Change and Gaze Sequence

The trajectory map records the movement path of the participant's line of sight in the VR scene, and the lines represent the trajectory of the subject's eye movements, and the depth of the color and thickness of the lines indicate the intensity and duration of the gaze, thus revealing the subject's attentional shifts and visual exploration patterns during the viewing process. In the trajectory diagram of the “Chairman

Mao in Xibaipo” scene (see Figure 3), we can observe a series of dense lines, which indicates that subjects engaged in frequent visual shifts and prolonged gaze in this exhibit. In contrast, the trajectory maps of the Preamble scene show fewer lines and lower gaze intensity (see Figure 4), implying that this area did not attract the same level of attention from the subjects. This difference in the trajectory maps suggests that the content and design of the exhibition play a crucial role in directing the visual attention of the audience.



Fig 3. “Chairman Mao in Xibaipo” trajectory map



Fig 4. “Foreword” trajectory map

4. Design Strategies for Enhancing VR Exhibits

In the field of educational exhibition design, attracting and maintaining students' attention plays a crucial role in enhancing the learning effect of the exhibition. Through in-depth analysis of students' visual attention and understanding of individualized learning needs, designers can create VR exhibitions that are both educational and stimulate students' interest.

(1) The connection between exhibition design and students' attention span

Teachers and designers need to explore how to utilize visual elements and exhibition content to enhance students' participation and learning effectiveness according to teaching needs. For example, the success of the “Chairman Mao in Xibaipo” exhibition in this study highlights the central role of storytelling in attracting students' attention. When designing the exhibition hall, designers should dig deep into the background stories of historical figures and events, and enhance the educational value and emotional resonance of the exhibition through contextualization and narrative description. At the same time, the rational use of multimedia and interactive technology, such as adding some audio commentaries and historical reenactment movies in the exhibition area, can effectively enhance the vividness and attractiveness of the stories.

In addition, in order to facilitate students to quickly identify and focus on the core content of the exhibition, designers also need to consider how to apply visual design principles to emphasize the key messages of the exhibition, so as to optimize the teaching materials and exhibition content. During the design process, designers need to fully utilize visual design principles such as contrast, repetition and alignment to highlight the key information of the exhibition, and at the same time rationally arrange the exhibition space to ensure that the key exhibits or information are located in a position that is easy to be observed, so as to guide the flow of the students' eyes and the allocation of their attention.

(2) Design and implementation of personalized learning

VR educational environments provide opportunities for personalized learning. By analyzing students' visual attention data, designers can create different learning experiences and interactive sessions for students with different learning styles. For example, for hands-on learners, the "Spirit of Spaceflight" exhibition area can be designed to simulate the interaction of spacecraft piloting, allowing students to experience the feeling of piloting a spacecraft by operating the simulated controller. This kind of interactive experience can not only increase the participation of learners, but also help them master knowledge in practice and enhance the depth and durability of learning.

The design of the interactive session can set up problem-solving tasks, such as simulating a space emergency and requiring students to work in teams to find solutions. Such tasks are not only challenging, but can also stimulate students' curiosity and desire to explore and promote their deep learning in the process of problem solving. Meanwhile, role-playing games and simulation experiments are also good forms of interaction, and they enable students to experience the work of astronauts in a simulated situation, enhancing the practicality and fun of learning.

(3) Optimization of exhibition layout and navigation

Optimizing the exhibition layout and navigation system is crucial to enhancing students' visiting experience and learning effectiveness. A well-designed spatial layout and navigation system can not only guide students to visit the exhibition smoothly, but also promote students' understanding and memory of the exhibition content. Using the results of trajectory mapping analysis, designers can optimize the layout of the exhibition to ensure that students can naturally transition from one section to another and stay focused on key information.

Designers can use continuity design elements such as colors, shapes, or themes to connect different exhibit areas so that students can visually feel the connection between the various exhibit areas. At the same time, ensuring visual fluidity during the visit by minimizing unnecessary corners and obstacles will help maintain students' attention and interest. Providing touchscreens with maps of the exhibition areas and summaries of the contents at prominent locations, as well as setting up clear signs and signage, can help students find the exhibition areas more easily and fully understand how to participate in the interactive learning process.

5. Conclusion

This study provides valuable real-time data and objective feedback for VR exhibition design through the use of eye-tracking technology, which makes the layout and presentation of exhibition content more scientific and precise. The data analysis revealed which exhibition elements were effective in attracting students' attention and how storytelling and contextualization strategies could enhance students' learning interest and engagement. The application of VR technology significantly enhanced students' attention and interest, especially through the introduction of specific design elements, such as the introduction of historical figures and scenes of important events, which further contributed to the enhancement of learning outcomes.

Although this study provides initial insights for understanding the impact of VR exhibition design on students' visual attention, there are some limitations. The small sample size and limited age range may limit the generalizability of the findings. In addition, data collection relied primarily on eye-tracking technology, which failed to fully capture cognitive and affective responses during the learning process. Future studies should expand the diversity and size of the sample to cover students of different age ranges and cultural backgrounds to improve the generalizability of the findings. Also, combining multimodal data, such as physiological measures and self-reports, provides a more comprehensive perspective for understanding students' learning experiences.

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