Article

Research on Visual Appeal in Element Design for Virtual Reality Thematic Digital Exhibitions

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Abstract: With the rapid development of information technology, the application of virtual reality (VR) technology in the field of digital exhibition has attracted wide attention, providing visitors with a new interactive experience. The purpose of this study is to explore the influence of different elements design on audience visual attraction in virtual reality digital exhibition. By using eye tracking techniques and in-depth interviews, this study analyzed the visual behavior patterns of visitors during the exhibition to assess the specific effects of different design elements on attention allocation. The study involved 30 graduate students in the School of Design and Art, using the aSee Pro desktop eye tracker to collect data. Based on the grounded theory, the interview data were coded and analyzed in depth, so as to further verify the conclusions of the eye tracker data analysis. By combining interview and eye-tracking data analysis, this study provides empirical support and in-depth understanding for the planning and optimization of digital exhibitions, and offers a new theoretical perspective and methodological reference for related fields, possessing significant value.

Keywords: eye tracker; digital exhibition; virtual reality; element design

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1. Introduction

With the rapid evolution of information technology, Virtual Reality (VR) has become a dynamic field, offering users immersive experiences. As VR technology continues to advance, themed virtual reality digital exhibitions are gaining prominence as platforms for showcasing products and services.

In thematic Virtual Reality Digital Exhibitions, designing captivating scene layouts and elements to maximize audience attention and engagement poses a significant challenge for exhibition planners. Since visitors' attention is a limited resource, every design element in an exhibition may influence their experiential outcomes. Therefore, gaining a deep understanding of the mechanisms through which various design elements affect audience attention is crucial for the successful creation of thematic Virtual Reality Digital Exhibitions.Through empirical research, we aim to provide designers with scientific insights to enhance visitor attention and overall exhibition quality.

2. Literature Review

2.1. Application of Virtual Reality Technology in Digital Thematic Exhibitions

With the continuous advancement of technology, virtual reality (VR) technology has been applied across various industries, providing technical support and new directions for development. Virtual reality scene digital exhibitions enrich participants' sensory experiences, fostering deeper immersion and understanding of exhibit backgrounds and significance compared to traditional static displays. Thematic exhibitions leverage virtual reality to elevate visual design, diversify exhibit presentations, and underscore thematic focus, enhancing visitor engagement.

2.2. Element Design in Digital Exhibitions

The cross-industry application of exhibitions compels designers to adopt new technologies and methods to enhance participant experiences and emotions [4]. It also promotes technological innovation, prompting the technology of thematic digital exhibitions to keep pace with the development of current high-tech [2]. Through software technology, big data analytics, etc., it is possible to understand the impact of different elements in digital exhibitions on user appeal [3], providing planners with a scientific basis for innovative design, and ensuring a clearer and more immersive digital exhibition experience for participants [5].

2.3. Review and Limitations in the Study

Most of the existing literature studies have summarized the gradual transformation from traditional physical exhibitions to digital exhibitions and the development trend of digital exhibitions, the importance of virtual reality technology in digital exhibitions, and the application of virtual reality technology in digital exhibitions. However, there is a lack of relevant literature on the use of the combination of eye tracker and in-depth interview analysis to perceive and probe the user's behavior in the design of thematic digital exhibition elements, visual research, attention influence and element attraction research in digital exhibition. Many existing studies lack the empirical data support of large-scale samples and in-depth interpretation and analysis of eye movement data, and cannot fully understand the attention distribution and behavior pattern of viewers when watching display content, which leads to questions about the universality and reliability of research conclusions. Therefore, by tracking the experimental data of the eye tracker and analyzing the results of the in-depth interview questionnaire, this study further explored the influence of the layout element design of the virtual reality special digital exhibition scene on the distribution of human attention, so as to provide the scientific basis for the exhibition planner to optimize the design.

3. Research Methods

3.1. Experimental Materials

This experiment mainly explores the layout elements design of virtual reality scene thematic digital exhibition to guide consumers' visual perception and attention through the analysis of eye tracker. Therefore, we chose to display four pictures of different locations of VR Pavilion of Wuhua County Planning Museum on the computer display connected with aSee Pro desktop eye tracker (see Figure 1), and collected and recorded relevant eye movement data of participants.

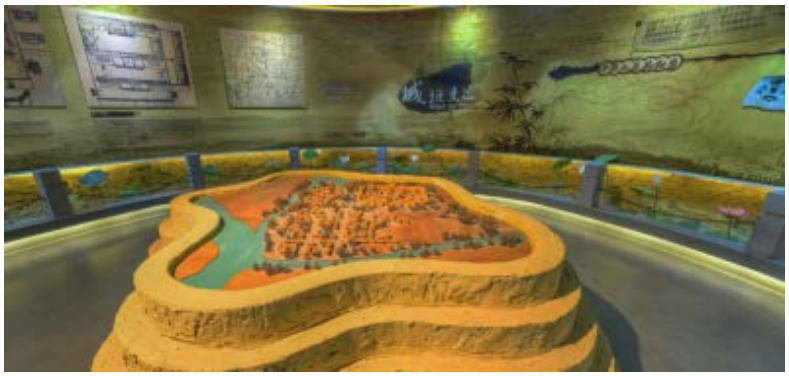

Figure 1. Wuhua County planning museum digital exhibition.

3.2. Subjects

In this study, 30 subjects (all graduate students) from the School of Design and Art of Jiangxi University of Finance and Economics were selected to display the virtual reality digital exhibition pictures of Wuhua County Planning Museum under the same experimental conditions. Considering the particularity of the eye tracker experiment, in order to reduce the interference of special external factors, the following requirements were carried out: the subjects had normal vision; If you wear glasses, the lenses must not exceed 500 degrees; Clear exposure of eyes and pupils. The experimenter avoided large amounts of twisting during the experiment. All the participants had some ability to appreciate art.

3.3. Experimental Equipment

For this experiment, we used the aSee Pro desktop eye tracker, which supports the addition of images, videos, and other materials for our experiment management, design, collection, and analysis needs. And it can be connected to a computer screen, allowing participants to watch various experimental stimuli. In addition, participants were not required to wear any devices to record their eye movement data.

3.4. Experimental Procedure

The test site of this study is the eye tracker laboratory of Jiangxi University of Finance and Economics. The indoor light is soft, the experimental environment is constant, and there is no external interference. Before the start of the experiment, the researchers will introduce the process and precautions of the experiment to the experimenters in detail, and manually calibrate the eye tracker to ensure the smooth progress of the experiment and the accuracy of the collected data to reduce the impact of errors. After the experiment began, the subjects were asked to remain seated and then look at four pictures of different positions in the VR pavilion of Wuhua County Planning Museum, each picture lasted for 12 seconds. During this period, the eye movement data of the participants during viewing was recorded by the aSee Pro desktop eye tracker for subsequent data analysis.After the end of the experiment, the subjects were interviewed in depth to obtain their subjective description and feedback, as well as their psychological activities and feelings during the viewing process.

3.5. Data Collection and Analysis Method

The Area of Interest (AOI) refers to specific visual data regions with specific relevance, typically used to study the relationship between specific types of images and subjects' visual attention [1]. In this study, by analyzing viewers' visual attention while appreciating the virtual reality scene of the Wuhua County Planning Pavilion, the area was divided into four main AOI zones: exhibit area, information display area, environmental background area, and decorative area (as shown in Figure 2).To evaluate how much attention each participant allocated to different layout elements in the VR digital exhibition of the Wuhua County Planning Pavilion during the experiment, we recorded four AOI indicators: maximum gaze duration [6], total gaze duration, gaze frequency, and visit frequency [7].

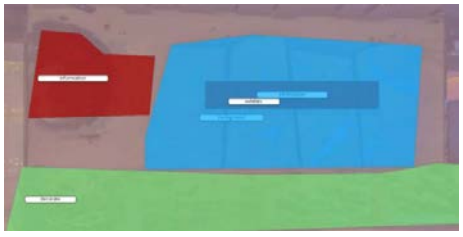

Figure 2. AOI regional division.

4. Eye Movement Experiment Results and Analysis

4.1. Analysis of Eye Movement Data in Areas of Interest

In this experiment, SPSS 25.0 was used for data analysis, and a total of 30 groups of participants' eye movement data were collected. Samples with low collection rate were excluded, and 25 participants' samples were left (as shown in Figure 3). We performed repeated measure ANOVA for maximum gaze duration, total gaze duration, number of looks, and number of visits for the four elements. The results are shown in Table 1:

For the gaze frequency of the four different elements, the repeated measures ANOVA showed a significant difference, with $F=436.947$, $p<0.001$. Post-hoc multiple comparisons revealed that the average gaze frequency for the background (16.22) was slightly higher than that for the display (12.33), both of which were significantly higher than those for information (4.35) and decoration (2.24).

For the visit frequency of the four different elements, the repeated measures ANOVA also showed a significant difference, with $F=48.636$, $p<0.001$. Post-hoc multiple comparisons indicated that the visit frequencies for the display (3.46) and information (3.36) were similar but significantly higher than those for the background (1.33) and decoration (1.37), with no significant difference between the background and decoration.

After excluding samples where the maximum gaze onset duration for a certain type of element was not recorded due to participants not fixating on that type of element, a repeated measures ANOVA was conducted on the maximum gaze onset duration for the four different elements. The results showed a significant difference, with $F=42.361$, $p<0.001$. Post-hoc multiple comparisons revealed that the background (2.058s) and display (1.991s) had similar durations, with the background slightly longer. Both the background and display had longer durations than information (1.14s), and significantly longer durations than decoration (0.421s).

Finally, a repeated measures ANOVA was conducted on the total gaze duration for the four different elements, yielding a significant difference with $F=288.397$, $p<0.001$. Post-hoc multiple comparisons showed that the background (8.630s) had the longest total gaze duration, followed by the display (6.999s) and information (2.684s), while the decoration (0.801s) had the shortest total gaze duration.

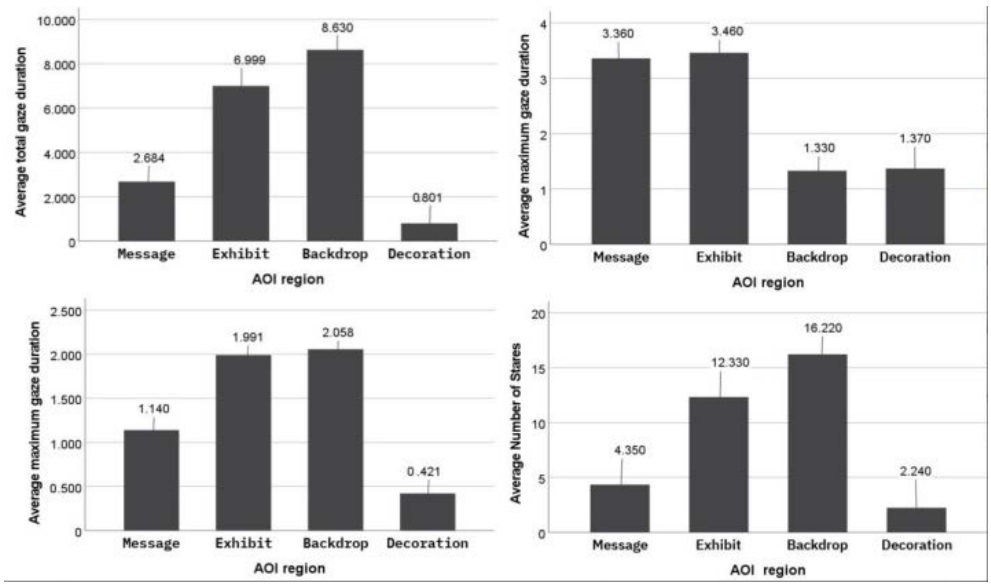

Figure 3. Eye movement data analysis bar chart.

Table 1. Repeated measure analysis of variance.

norm	Levene's test for chi-square		ANOVA test		
	Sig	Df	mean square	F	Sig
Maximum fixation duration	0.000	3.	1332.417	436.947	0.000
Maximum gaze duration	0.000	3.	60.290	42.361	0.000
Number of visits	0.000	3.	141.646	48.636	0.000
Number of gaze	0.000	3.	4345.08	288.397	0.000

4.2. Analysis of Eye Movement Heat Maps

The eye movement data for each participant was summarized and represented as an eye movement heat map, using colors such as green, yellow, orange, and red to indicate how much attention the participant paid to different elements. Areas with no color or green indicated the least attention, yellow and orange areas indicated more attention, and red areas indicated the most attention of the participants. A number of representative heat maps were selected from the participants' heat maps for analysis(as shown in Figure 4).

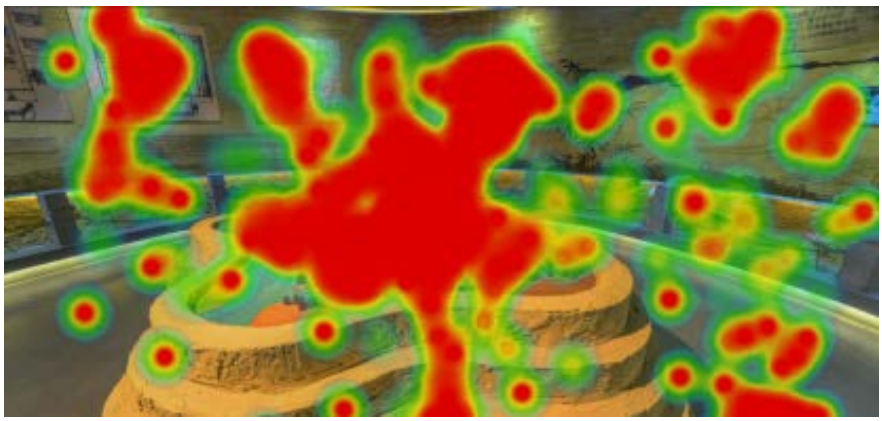

Figure 4. Eye movement heat map.

5. Interview Analysis Based on Grounded Theory

Through the design and implementation of the interview questionnaire, we collected the interview data of all subjects, and used the rooted theory to conduct open coding, spindle coding and selective coding to conduct in-depth analysis of the collected interview data. Through in-depth interviews with the subjects, the accuracy and value of the conclusions of the eye tracker data analysis were further verified.

In terms of viewing experience, most of the participants said that the exhibits and backgrounds in the digital exhibition elements are most likely to attract their continuous attention; In terms of the allocation of attention, most participants said that they felt that the exhibits did attract their attention more than other elements during the viewing process. Because the exhibits show the theme and content of the exhibition, with a unique form, color or function, they can quickly catch the eye of the viewer. In addition, the background and decorative elements play a role in creating atmosphere and adding interest to the viewing in terms of attracting attention. A well-designed background can make it easier for people to immerse themselves in the exhibition, while decorative elements can increase the interest and enjoyment of the exhibition, so that people do not feel monotonous. The information element plays a necessary role in explaining and supplementing the exhibition. For example, some exhibitions use QR codes or interactive screens to allow visitors to scan or click for more information. This interactive approach not only allows the audience to choose what they want to know, but also increases the interest and participation of the exhibition.

6. Discussion and Conclusion

6.1. Discussion

This study mainly uses eye-tracking equipment to explore how the layout design of virtual reality digital exhibition affects users' visual attention. It reveals that participants predominantly focus on the background, followed by exhibits, while information and decorations receive less attention. These findings underscore the importance of optimizing design elements for enhancing user engagement.

In this study, the combination of exhibits and information is the key to achieve visual attraction. The exhibits are the core content of the exhibition, and the presentation of information should also be coordinated with the exhibits, through text, images, audio and other ways to provide the audience with rich background knowledge and interpretation. Decorative and background elements are equally important in digital exhibitions dedicated to virtual reality. Decorative elements can enhance the visual impact of the exhibition and enhance the viewing interest of the audience through color, material, light and shadow and other means. The background elements can provide a suitable display environment for the exhibits and create an atmosphere that matches the theme. Through the rational use of these elements, a highly immersive and interactive exhibition environment can be created to bring unique exhibition experience to the audience.

Through empirical research, we aim to provide designers with insights to enhance visitor attention and overall exhibition quality. By analyzing the appeal of different design elements using eye-tracking technology, we continuously refine virtual reality exhibition design strategies to offer a richer experience. The integration of exhibits, information, decoration, and background elements creates an immersive environment, deepening audience understanding and memory of the exhibition theme. This immersive experience fosters improved aesthetic ability and cultural literacy, positively impacting long-term development.

Through empirical support and in-depth understanding, the analysis of eye movement data provides objective and quantitative evidence, directly showing the audience's gaze time and frequency on different elements, and provides accurate data support for researchers. The in-depth interview obtained the subjective description and feedback of the participants, revealed the audience's psychological activities and feelings during the viewing process, and provided in-depth insights for understanding the audience's behavior and attention allocation. The combination of the two enables the research to comprehensively analyze the audience's attention distribution in the digital exhibition from both objective and subjective levels, and build a more comprehensive and comprehensive perspective. This comprehensive perspective helps to reveal the complex mechanism of audience's attention allocation in digital exhibitions, and provides a more scientific basis for exhibition design and optimization. The research results can provide specific practical guidance for digital exhibition planners and designers to help them optimize exhibition layout and element design to better attract audience's attention. For example, based on the results of the study, curators can better highlight the design of the exhibits, increase the readability and comprehensibility of the information, while appropriately adjusting the visual impact of the background and decorative elements.

6.2. Limitations and Future Research

Although this study combines interviews and eye movement data analysis to provide abundant data and theoretical support for subsequent research, it also provides a new theoretical perspective and methodological reference for research and practice in related fields. It can inspire other researchers to further explore other influencing factors of audience attention in digital exhibitions, but its limitation mainly lies in the sample selection, which is limited to students in specific colleges, and may affect the universality of conclusions. Additionally, relying on eye-tracking technology may not comprehensively capture

visitors' emotional and cognitive responses, indicating the need for more diversified research methods.Future research should consider including a broader range of participant groups to enhance the generalizability of the study and adopt a diversified research strategy that combines quantitative and qualitative methods to delve into the comprehensive experiences of the audience. Moreover, exploring the application of novel virtual reality technologies in different fields and their impact on user experience is also an important direction for future research, contributing to providing more comprehensive theoretical and practical guidance for the development and application of virtual reality technology.

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References

1. De Smet, B., Lempereur, L., Sharafi, Z., Guéhéneuc, Y. G., Antoniol, G., & Habra, N., "Taupe: Visualizing and analyzing eye-tracking data," *Science of Computer Programming*, vol. 79, pp. 260–278, 2014.
2. Li, Q., Wang, J., & Luo, T., "Evaluating interactive digital exhibit characteristics in science museums and their effects on child engagement," *International Journal of Human–Computer Interaction*, vol. 3, pp. 838–849, 2024.
3. Liu, Z., & Chang, S., "A study of digital exhibition visual design led by digital twin and VR technology," *Measurement: Sensors*, vol. 100970, 2024.
4. Luo, X., Wang, Y., Lee, L. H., Xing, Z., Jin, S., Dong, B., ... & Hui, P., "Using a virtual reality interview simulator to explore factors influencing people's behavior," *Virtual Reality*, vol. 1, 2024.
5. Xia, Y., Deng, Y., Tao, X., Zhang, S., & Wang, C., "Digital art exhibitions and psychological well-being in Chinese Generation Z: An analysis based on the S-O-R framework," *Humanities and Social Sciences Communications*, vol. 1, 2024.
6. Costa, M., Simone, A., Vignali, V., Lantieri, C., & Palena, N., "Fixation distance and fixation duration to vertical road signs," *Applied Ergonomics*, vol. 69, pp. 48–57, 2018.
7. Ding, Y., Naber, M., Paffen, C., Gayet, S., & Van der Stigchel, S., "How retaining objects containing multiple features in visual working memory regulates the priority for access to visual awareness," *Consciousness and Cognition*, vol. 87, p. 103057, 2021.