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A Study on the Visual Appeal of Eco-Friendly Natural Elements in Metaverse 3D Game Environments

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Abstract. This research endeavors to delve deeply into how various eco-friendly natural elements captivate players' visual attention within the 3D game environments of the Metaverse. We selected still frames from "theHunter: Call of the Wild," a game rich with natural elements, and conducted empirical studies on specific demographics using eye-tracking technology. The results reveal that players' visual focus is significantly drawn more to certain natural elements like trees and mountains compared to others such as skies and lakes within the game. This insight is crucial for game designers, offering practical guidance on utilizing natural elements effectively to optimize visual design, enhance the game's allure and educational value, and spur innovation and advancement in the field of Metaverse 3D gaming. By tailoring the incorporation of these elements, designers can create more engaging and meaningful experiences within the expansive realm of the Metaverse.

Keywords. Eye-tracking experiments, metaverse games, natural elements, ecological design

1. Introduction

The Metaverse, a virtual three-dimensional environment offering immersive experiences [1], is seeing a growing focus on its eco-friendly natural elements among researchers and developers. Game developers simulate real-world natural elements like trees, lakes, and mountains to deliver more realistic and enriched user experiences. The visual attention and appeal these elements garner from users reflect their cognitive and emotional preferences towards them, subsequently impacting their gaming experiences and satisfaction [2].

This study chose "theHunter: Call of the Wild" as the subject, a game widely appreciated for its abundant natural landscapes and exquisite scenery. It is connected to the concept of the Metaverse as it embodies some key characteristics of it, despite being primarily a hunting-themed game. This game creates an immersive virtual gaming environment, with the theme centered around players experiencing hunting in various types of natural landscapes. In the game, players can take on the role of a

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hunter, picking up a hunting rifle and tracking animals with friends to enjoy the thrill of the hunt. Alternatively, players can also play as tourists, using binoculars and cameras to immerse themselves in the distinctive nature reserves, enjoying the beautiful and realistic natural scenery. It simulates real forest environments and hunting experiences through highly realistic graphics and sound, and considerations of animal behaviors, senses, wind direction, etc., epitomizing the authenticity and simulation sought in the Metaverse. Players can not only interact with the game environment and animals but also engage and socialize with other players, reflecting foundational activities in the Metaverse. The presence of a virtual economic system is common in the Metaverse, and in "theHunter: Call of the Wild", players earn virtual currency and rewards through hunting, depicting value creation and exchange in the virtual world. The game's environment and mechanics are a re-creation of the real world.

This research aims to explore comprehensively the impact of various eco-friendly natural elements in Metaverse 3D game environments on user visual attention. Specifically, this study addresses three sub-questions: Which type of eco-friendly natural element attracts user visual attention the most in Metaverse 3D game environments? Does the distribution of visual attention across different natural elements vary under different game environments and conditions? Is there, in most cases, a natural element that primarily captures user visual attention?

2. Literature Review

2.1. Application of Visual Attention in Game Design

Based on the concepts of the human visual system, computational visual attention seeks to identify regions of interest within images [3]. In games, visual attention is typically studied by recording the eye movements of participants as they observe game scenes during gameplay [4]. Visual attention holds paramount significance in game design [5]. Previous research indicates that in-game visual elements, color combinations, shape designs, and layout structures all impact players' visual attention, subsequently affecting their cognition and experience of the game [6,7]. For instance, studies by Samad and Forouzandeh have shown through experimental research that considering the principles of color psychology in game design can enhance immersion for normal vision players, influencing their performance and behavior [6]. Qin's research discovered that game elements supporting autonomy and relatedness affect the satisfaction of these needs, thereby increasing game enjoyment and continued play [7]. Additionally, visual design can guide players to focus more on elements closely related to the game's objectives, avoiding excessive attention to non-core elements.

2.2. Visual Tracking in Games

Despite extensive research on visual tracking in game design, many researchers have utilized eye-tracking technology to study the visual appeal of elements within games. El-Nasr conducted eye movement experiments to demonstrate the relationship between players' attention and the levels and scenes of a game [8]. Samuel investigated how scenic elements like buildings, walls, and cars influence players' visual attraction and gaming experience [9]. Similarly, Jiang used eye-tracking to record data such as the

number of gazes and scans, exploring the impact of game interface interaction on players' willingness to engage [4]. Eye-tracking technology has found widespread application in the field of gaming. However, a profound discussion is still lacking regarding how natural elements visually attract players. Natural elements, like trees, lakes, and mountains, are vital components in constructing game worlds, with their visual representation influencing players' overall perception of the gaming environment.

2.3. Review of Research and Gaps in the Literature

While the importance of visual attention has been acknowledged in game design, current research primarily focuses on game interface and character design, with relatively less in-depth exploration on the visual appeal and representation of natural elements. In these studies, detailed interpretations and applications of how natural elements visually attract players are seldom discussed.

Under these circumstances, the evident research gap and lack of studies on the visual representation and design methods of natural elements in games have undoubtedly constrained our comprehensive understanding and application of visual attention in game design. Therefore, this study emphasizes eco-friendly natural elements in Metaverse 3D game environments, aiming to deepen our understanding of their visual appeal and explore how to implement these natural elements more effectively in game design.

3. Research Methodology

3.1. Experimental Materials

Given the focus on natural elements in games for this study, we have chosen the game "theHunter: Call of the Wild," developed by Expansive Worlds. The game's production team has created several open-world hunting maps, each with distinctive landscapes and rich natural elements. For example, there's the Layton Lake District, nestled among mountains and waterways, and the snow-covered peaks of Silver Ridge. Dozens of images featuring diverse natural elements and scenic beauty were selected from the game. After an expert panel reviewed and eliminated images with distracting elements, we finalized four representative images depicting a forest road, a riverbank overgrown with aquatic plants, a lakeside, and a snowy plateau.

3.2. Participants

Thirty students and faculty members from university, consisting of 19 females and 11 males, all with gaming experience, were selected as subjects. Due to the specificity of eye-tracking experiments, to avoid external interference, participants were required to follow certain guidelines: no wearing of contact lenses; if wearing glasses, the lens prescription should not exceed 500 degrees; no excessive eyelash length or eye makeup; normal eye function with no recent eye surgeries. After the experiment, each participant received a 10 RMB cash reward.

3.3. Experimental Apparatus

The study utilized the aSee Pro remote eye tracker, known for its high sampling rate and user-friendly installation. The data recording software chosen was aSeeStudio eye movement analysis software, compatible with the eye tracker. Additional equipment included a computer and display screen connected to the eye tracker and a dongle required by the eye-tracking software.

3.4. Experimental Procedure

The experiments were conducted indoors in a laboratory, starting at seven in the evening to ensure stable indoor lighting and to avoid interference from external light sources like sunlight. After each participant was ready, a nine-point calibration procedure for the eye tracker was initiated, and participants were informed that they would view four screenshots from the game. Participants were asked to view the images as if they were playing the game, with 15 seconds allotted per image, allowing participants free viewing without instructions.[10].The experiment automatically concluded after viewing all images. The first image was not included in the data analysis; its purpose was to quickly acclimate participants to the experiment to avoid experimental error, and the subsequent three images were recorded and analyzed.

3.5. Data Collection and Analysis Method

AOI (Areas of Interest) were designated to analyze players' attention distribution to the game scenes during gameplay. The green ecological elements in the three game screenshots were divided into multiple, varying-sized AOI areas (as shown in Figures 1). Screenshot 1 was divided into five AOI areas: sky, trees, lake, grassland, and rocks. Screenshot 2 was divided into sky, trees, lake, grassland, and mountains, and Screenshot 3 was divided into sky, trees, grassland, and mountains. To examine each participant's attention allocation to each natural element during the experiment, we recorded and analyzed the following indices in each AOI area: Total Fixation Duration within an AOI area, indicating the sum of all fixation times, measured in seconds, with longer durations implying higher attention levels. Additionally, the Number of Viewers and Number of Fixations within the AOI area were recorded to validate the user's level of attraction to the elements [11]. The higher the number of user attentions in an AOI (Area of Interest) region, the more it indicates that the area is capable of capturing the user's attention. The number of gazes at an AOI, which refers to the number of times users look at that area during an experiment, effectively demonstrates the area's attractiveness to users. More gazes suggest greater user attraction to the area, and vice versa. To study which natural element would capture participants' attention first, we incorporated the duration before the first gaze at an AOI, recording the time it takes for a user to first notice an AOI region. The shorter the duration of the first gaze, the quicker an AOI region attracts the user's attention. If an AOI region lacks data on the duration of the first gaze, it implies that the participant did not gaze at that AOI.

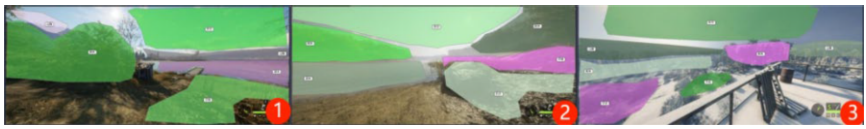

Figure 1. Division of AOI Areas in Game Screenshot 1，Game Screenshot 2，Game Screenshot 3

4. Eye Movement Experiment Results and Analysis

4.1. Analysis of AOI Eye Movement Data

In this experiment, eye movement data was collected from 30 participants. After excluding samples with a low degree of collection, a total of 28 sets of experimental data were preserved, after averaging. A repeated measures variance analysis was conducted on the number of fixations, total fixation duration, time to first fixation, and the number of viewers for six natural elements, with results shown in Table 1.

For the number of fixations, a repeated measures variance analysis revealed significant differences in the experimental data, $F(5,386) = 13.798$, $p \leq 0.001$. Post-hoc multiple comparisons showed that the average number of fixations on trees (6.023) was significantly higher than rocks (3.64) and mountains (3.445). The difference in the number of fixations between rocks and mountains was not significant, but both were significantly higher than the sky (2.857). Lakes (2.09) and grasslands (2.033) had significantly fewer fixations than the other four elements.

For the total fixation duration, a repeated measures variance analysis indicated significant differences, $F(5,386) = 9.620$, $p \leq 0.001$. Post-hoc multiple comparisons revealed that the average total fixation duration on trees (1.623s) was significantly longer than the sky (0.9s), rocks (0.825s), and mountains (0.882s). The total fixation durations for the sky, rocks, and mountains were not significantly different from each other but were significantly longer than lakes (0.662s) and grasslands (0.535s). After excluding samples that did not record the time to first fixation for certain elements due to lack of attention to those elements, a repeated measures variance analysis for time to first fixation showed significant differences, $F(5,301) = 6.611$, $p \leq 0.001$. Post-hoc multiple comparisons showed that the average time to first fixation was significantly longer for grasslands (5.625s), the sky (4.948s), and lakes (4.625s) compared to the other three elements. Among them, grasslands had the longest time to first fixation, followed by the sky and lakes, with mountains (3.763s) and rocks (3.758s) showing no significant difference, and trees (2.406s) having the shortest time to first fixation.

A repeated measures variance analysis on the number of viewers revealed significant differences, $F(5,386) = 4.242$, $p \leq 0.001$. Post-hoc multiple comparisons revealed that trees (0.927) had the highest average number of viewers, followed by rocks (0.89), grasslands (0.777), mountains (0.75), and lakes (0.73), with the sky (0.663) having the least number of viewers.

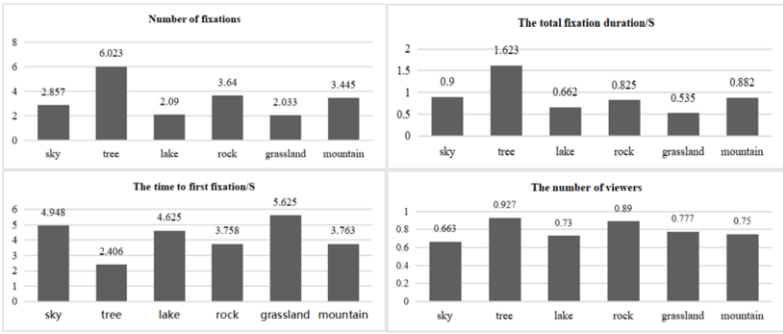

Figure 2. Bar Graph of Eye Movement Data

Table 1. Repeated Measures Analysis of Variance

Norm	Levene's test for chi-square		ANOVA test		
	Sig.	**df**	**mean square**	**F**	**Sig**
The number of fixations	0.000	5	173.580	13.798	0.000
The total fixation duration	0.000	5	8.889	9.620	0.000
The time to first fixation	0.000	5	86.879	6.611	0.000
The number of viewers	0.000	5	0.694	4.242	0.001

4.2. Analysis of Eye Movement Heat Map Data

An overlay analysis of the visual hotspots of each participant was conducted to generate heat maps. The heat maps use various colors, including light green, green, yellow-green, yellow, orange, and red, to represent the varying degrees of attention participants paid to different elements. Elements in the green areas received the least attention and were looked at for the shortest amount of time, while elements in the red areas received the most attention and were looked at for the longest amount of time.

Analysis of the eye movement heat map for game screenshot 1 revealed that participants' visual focus was primarily on the foreground rocks and trees, with less attention paid to the foreground lake and background sky. The eye movement heat map for game screenshot 2 indicates that participants paid more attention to foreground trees, background lakes, and background mountains, while there was little attention given to the background sky and foreground grassland. Analysis of the eye movement heat map for game screenshot 3 showed that participants generally focused on trees and mountains, with less attention given to the sky and grassland.

After summarizing and analyzing the eye movement heat maps for the three images, we found that regardless of the environment, participants paid more attention to trees and mountains compared to other elements, while the sky and grassland received significantly less attention. Furthermore, the location of the elements, such as

the trees in the foreground in screenshots 1 and 2, and even when located in the background in screenshot 3, still received the most attention from the majority of participants.

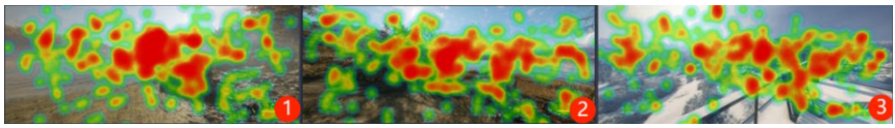

Figure 3. Eye Movement Heat Map of Game Screenshot 1，Game Screenshot 2，Game Screenshot 3

5. Conclusion and Discussion

5.1. Discussion

In this study, eye-tracking technology was employed as the primary method to gather data on users' attention to various natural elements in the game, examining how different natural elements influence players' attention. After analyzing the four sets of eye-tracking data, we made several meaningful discoveries.

Trees attracted the most gazes, followed by rocks and mountains, while the sky, lakes, and grasslands were less frequently observed. Therefore, in metaverse games, it would be strategic to place key objects and information around trees, mountains, and rocks, as these natural elements receive more attention from users.

The gaze duration on a particular natural element is an effective measure of its visual appeal [12]. Trees were the most focused-on element, with the longest total gaze duration, followed by the sky, rocks, and mountains. Lakes and grasslands received less attention. Hence, in the game, trees and the sky, among other natural elements, should be designed with more detail and variety, as they have the strongest visual appeal and will engage users for longer periods.

The elements that catch users' attention first, indicated by the shortest duration before the first gaze, were still trees, followed closely by mountains and rocks. Lakes, the sky, and grasslands were less likely to be noticed immediately. Game developers can consider placing game-related guidance around trees, mountains, and rocks, as these elements quickly attract players' attention.

Trees were also the elements that attracted the most number of gazes, followed by rocks, grasslands, mountains, and lakes, with the sky receiving the least attention. Analysis of the eye-tracking heatmaps further confirms these findings, showing that respondents in the game paid far more attention to trees, rocks, and mountains than other elements, with less focus on lakes and grasslands. Despite occupying a large AOI area, the sky attracted minimal attention. Thus, in 3D metaverse games, special attention should be given to natural elements like trees, rocks, and mountains, as they are the most engaging for players.

5.2. Theoretical Contributions

The primary theoretical contribution of this study is the enhanced understanding of the application of visual attention in game environments and an exhaustive exploration of the visual appeal of natural elements in games. This creates new opportunities and

perspectives for applying visual attention theory in digital gaming, establishing a foundation for future research, and also fills a gap to some extent in the field of ecological design, particularly in research related to metaverse game design.

By delving into the various eco-friendly natural elements within Metaverse 3D games, this study provides new theoretical insights into how to effectively implement these natural elements in game design. These findings enrich the theoretical framework of game design, especially offering new directions and insights for future research on ecological game design.

Moreover, by thoroughly analyzing the role and importance of natural elements in games, this study contributes new insights and knowledge to game design theory, aspiring to stimulate more research on game design and the interaction of visual attention, thus fostering the continuous development and refinement of related theories.

5.3. Practical implications

The findings of this study can offer practical guidance to game designers and developers, aiding them in more accurately utilizing natural elements to attract players' attention, optimize game design and user experience, enhance player satisfaction, and thereby increase the probability of commercial success of the games.

This study, analyzing the visual appeal of eco-friendly natural elements in Metaverse 3D games, provides new inspirations and directions for game designers, For example, game creators can place guides, markers, and key elements within the natural features that attract the most attention from players, allowing them to immerse more deeply in the Metaverse's 3D games, thereby promoting innovation and sustained development in the field of Metaverse 3D game design.

This study is poised to empower game designers to develop more educative games. By optimizing the visual representation of natural elements in design, games can more vividly and realistically portray the beauty and diversity of nature, educating players on ecological conservation and environmental awareness, and enhancing their environmental consciousness [13]. Ecological games offer a compelling way to convey environmental knowledge to players and foster eco-friendly principles, truly achieving education through entertainment.

Ultimately, by introducing more visually appealing elements and a more diverse and colorful game world, this study contributes to improving users' gaming experiences [9], enhancing their immersion and satisfaction in the game. It also aids game designers in better creating the Metaverse 3D games they aspire to develop.

5.4. Limitations and Future Research Directions

While this study has achieved some results in exploring the visual appeal of eco-friendly natural elements in Metaverse 3D game environments, there are limitations. In selecting subjects for the experiment, there are many influencing factors that require further exploration. The experimental materials chosen in this study are somewhat monotonous, lacking in scenarios featuring natural elements in different seasons and various climatic conditions. Landscape elements like seasonality, spatial background, etc., also influence participants' attention and visual behaviors[14]. In current 3D Metaverse games, accurately replicating natural climates is becoming increasingly important. A well-developed weather system can also impact the gaming experience. Therefore, future research needs to meticulously explore natural elements in different

climates. Besides, this study only explored the impact of natural elements in an ecological environment on players' visual attention, not considering the narrative style of the game, its mechanics, or individual characteristics of the players, leading to certain research blind spots. Future studies should comprehensively consider the significant or intersecting effects of various game elements on players' visual attention. Additionally, this research only considered one game. In subsequent studies, researchers should conduct comparative research on multiple types and quantities of games to enhance the universality of the conclusions.

Furthermore, eye-tracking technology has its limitations. The data recorded by eye-trackers can be influenced by external environments and various internal factors of the subjects. Also, the sample size in this experiment was small and may not represent all users of Metaverse 3D games. In future experiments, a more rigorous process should be used to minimize interference from factors outside the experiment, increase the sample size, and consider subjects with different characteristics.

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