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An Exploration of the Impact of VR/AR Game UI Optimization Schemes Driven by Eye-Tracking Feedback on User Experience

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Abstract: With the rapid development of virtual reality (VR) and augmented reality (AR) technologies, the gaming field has ushered in a brand-new interactive experience. The user interface (UI), as an important bridge for players to interact with the game, its design quality directly affects the user experience. Eye-tracking technology provides a new opportunity for the optimization of VR/AR game UI. This paper deeply explores the optimization schemes of VR/AR game UI driven by eye-tracking feedback, and analyzes the multi-faceted impacts of these optimization schemes on user experience, aiming to provide theoretical references for VR/AR game developers to improve the overall quality of the game and user satisfaction.

Keywords: Eye Movement Tracking Feedback; VR/AR Games; UI Optimization Plan; User Experience

1. Introduction

Virtual reality (VR) and augmented reality (AR) technologies, as popular development directions in the field of technology in recent years, are changing the landscape of the gaming industry at an unprecedented speed [1]. VR technology creates a fully immersive virtual environment, making users feel as if they were in a brand-new world. AR technology combines virtual elements with real scenes, bringing users a unique experience of the integration of the virtual and the real [2]. These two technologies provide game developers with a broad creative space, enabling games to make a qualitative leap in aspects such as interaction methods, visual effects and immersion.

The user interface (UI), as an important bridge for players to interact with the game, its design quality directly affects the user experience [3]. In traditional games, UI design has formed a relatively mature system. However, in VR/AR scenarios, due to the complexity and particularity of the interactive environment, traditional UI design methods often fail to meet the needs of users [4]. For example, in VR games, users are in a three-dimensional virtual space, and UI elements need to be presented in a three-dimensional and spatial way. Users need to view and interact by turning their heads and moving their eyes, which is quite different from the UI interaction methods on traditional two-dimensional screens [5].

Eye-tracking technology provides a new opportunity for the optimization of VR/AR game UI [6]. This technology can capture the user's gaze movement in real time, providing valuable information about the user's attention and points of interest for UI design [7]. By analyzing eye movement data, developers can understand the degree to which users pay attention to different UI elements during the game process, and thereby carry out targeted optimization of the UI to enhance the user experience [8]. Therefore, in-depth research on the impact of VR/AR game UI optimization schemes driven by eye-tracking feedback on user experience has important theoretical and practical significance.

2. Current Situation and Problems of VR/AR Game UI

2.1 Features of VR/AR Game UI

The UI of VR/AR games is significantly different from that of traditional games. In a VR environment, users are in a three-dimensional virtual space, and UI elements need to be presented in a three-dimensional and spatial way to adapt to the immersion of the virtual scene. For example, UI elements may be distributed in various directions around the user, and the user needs to view and interact by turning the head and moving the line of sight. This is just like in a real room where various items are distributed in different positions, and users need to turn their bodies and heads to see them [9].

AR games combine virtual elements with real scenes. The UI not only needs to integrate with the virtual game content but also consider the coordination with the real environment to avoid interfering with the real scene. For example, in an AR treasure hunt game, the prompt information of virtual treasures needs to be naturally integrated into the real scene and should not be too abrupt; otherwise, it will affect the user's real experience [10].

2.2 Problems Existing in the Current UI

In the current field of VR/AR games, some developers, in pursuit of comprehensive information, overly pile up content in UI design, resulting in the game interface being filled with a large amount of text, ICONS and buttons. In VR games, players are placed in a three-dimensional virtual space and inherently need to adapt to a complex visual environment. At this time, too many information elements are like a disorderly pile of items in front of them. For example, in a certain VR role-playing game, the screen interface simultaneously presents multiple contents such as the character's health points, magic points, skill cooldown times, task prompts, map information, and item bar status, with all kinds of information interwoven with each other. During the intense game process, players often find it difficult to quickly lock in key information from the complex interface within a short period of time, such as the skill cooldown time or task prompts that they urgently need to pay attention to at present. This situation of information overload greatly increases the cognitive burden of players. Players need to spend more energy and time screening and understanding the information, thereby distracting their attention from the core gameplay and plot of the game and reducing the smoothness and fun of the game.

The unique interaction methods of VR/AR devices, such as controller operation, gesture recognition and voice control, are significantly different from the keyboard, mouse or touchscreen operation of traditional devices. However, the UI design of some VR/AR games does not fully consider these interaction characteristics, resulting in operational difficulties for players during the gaming process. Take controller operation as an example. In some VR shooting games, the layout of operation buttons such as the shooting button, reammunition button, and weapon switching button is not reasonable enough. The distance between the buttons is too small or their positions do not conform to ergonomic principles. When players operate with the controller, they are prone to accidental touches or difficulty in accurately clicking the target button, which reduces the shooting accuracy rate and slows down the reloading action, seriously affecting the smoothness of the game operation and the combat experience. For gesture recognition interaction, if the UI elements are not optimized for gesture operations, such as buttons being too small or lacking clear gesture operation feedback, players will feel confused and struggling when performing gesture operations, unable to smoothly complete various interaction tasks in the game, thereby reducing players' satisfaction with the game.

When players are in a VR/AR environment for a long time, their eyes need to constantly adapt to the visual changes of the virtual scene, which itself is prone to causing fatigue. However, the UI design of some VR/AR games has obvious deficiencies in terms of visual comfort, further intensifying the visual fatigue of players. In terms of font design, some games adopt overly small fonts in pursuit of the so-called "refinement" or to save space. For example, in a certain VR strategy game, the font size of the text information in the game, such as task descriptions and the quantity of resources, is even smaller than the size required for players to read normally. Players have to squint laboriously to see the content clearly, which undoubtedly increases the burden on the eyes. In terms of color matching, the colors of some UI elements have insufficient contrast with the background color, making it difficult to clearly recognize the text or ICONS. For instance, in some AR puzzle games, the color of the prompt information is too similar to that of the surrounding real scene. When players are looking for the prompt information, they need to spend more time and energy. Their eyes remain in a tense focused state for a long time, which can easily lead to fatigue and soreness. In addition, overly dense UI elements are also an important factor leading to visual fatigue. Some game interfaces are densely arranged with various ICONS and buttons, lacking reasonable spacing and a sense of layering. This makes players feel confused and depressed when their eyes move on the interface, further aggravating the degree of visual fatigue.

3. UI Optimization Scheme for VR/AR Games Driven by Eye-Tracking Feedback

3.1 UI Layout Optimization Based on Eye Movement Hotspots

Eye-tracking technology can record the user's gaze movement trajectory during the game process, generate eye movement hot spot maps, and visually display the areas that the user focuses on. Based on the eye movement hot spot map, developers can optimize the UI layout. Place important UI elements, such as game menus, task prompts, and health value displays, in areas where users' lines of sight frequently linger to enhance the efficiency of users' information acquisition. For example, in VR shooting games, the amount of ammunition is displayed in the lower right corner of the player's field of vision, because this area is usually the place that the player's line of sight can easily reach during the shooting process. Meanwhile, reduce the occupation of unnecessary UI elements in the hotspot area to avoid information interference.

3.2 Dynamic UI Display and Hiding

Dynamic display and hiding of the UI can be achieved through eye-tracking feedback. When the user looks at a certain area, the relevant UI elements are displayed automatically. When the user's gaze moves away, the UI elements are hidden. This approach can reduce the occlusion of the game screen by the UI and maintain the immersion of the game scene. For example, in AR exploration games, when a user gazes at a certain virtual item, the detailed information UI of that item is displayed; when the user's gaze leaves, the UI automatically disappears, allowing the user to focus more on the integration experience of the real scene and virtual items.

3.3 Personalized UI Customization

There are differences in visual habits and operational preferences among different users. Eye-tracking technology can collect users' gaze data and interaction behaviors, and generate personalized UI configurations for each user. For example, automatically adjust the size and color of UI elements based on the user's gaze duration to make them more in line with the user's visual needs. For users who are accustomed to operating with their right hand, the frequently used operation buttons can be placed on the right side of the screen. For users who are accustomed to using their left hand, place it on the left side. Through personalized UI customization, enhance users' adaptability and satisfaction with the game.

3.4 Interactive Feedback Optimization

Eye-tracking feedback can also be used to optimize interactive feedback. When a user looks at an interactive UI element, clear interaction prompts are given to the user by changing the appearance, color or adding animation effects of the UI element. For example, when a user looks at a button, the button glows slightly or shows a slight shake, letting the user know that the button can be interacted with. Meanwhile, after users perform interactive operations, provide visual, auditory or tactile feedback in a timely manner to enhance users' operational perception.

4. The Impact of VR/AR Game UI Optimization Schemes Driven by Eye-Tracking Feedback on User Experience

4.1 Enhance Cognitive Efficiency

In the complex virtual environment of VR/AR games, the rapid and accurate acquisition of information is crucial for players' gaming experience. The UI optimization scheme driven by eye-tracking feedback plays a significant role in improving the cognitive efficiency of players.

UI layout optimization based on eye movement hotspots is like opening up a "high-speed channel" for players to obtain information. Developers collect players' gaze data during the game process through eye-tracking technology, draw eye movement hotspots, and thereby accurately locate the areas where players' gazes frequently stay. Place the key information in the game, such as task objective hints, important item descriptions, and character status information, ingeniously in these easily accessible areas. For example, in a VR fantasy adventure game, after players enter the game, the primary task is to understand the current main quest. Through the analysis of eye movement hotspots, it was found that at the beginning of the game, players' gazes were mostly concentrated in the upper center of the screen. So, the developers displayed the main quest prompts in the form of prominent fonts and ICONS in this area. Players no longer needed to search around in the complex interface. They

could obtain the key quest information at a glance, greatly reducing the time spent looking for information.

The dynamic UI display and hide mechanism is like a smart information filter, effectively avoiding the problem of information overload. During the game process, not all information needs to be presented to the players all the time. Dynamic UI can intelligently display and hide relevant UI elements based on the player's line of sight and the game progress. When players focus on exploring a certain scene, UI elements irrelevant to the current task are automatically hidden, and only the information related to scene interaction and task advancement is retained. For instance, in an AR treasure hunt game, while players are searching for treasures, the markings of other areas on the map and information about irrelevant items will be temporarily hidden, highlighting only the treasure clues and surrounding environment information of the current area. In this way, players can focus more on the information related to the current task, concentrate their attention on the key content, thereby improving the cognitive efficiency of game information. They can understand the game rules, task goals and operation methods more easily, reduce the frustration caused by the difficulty in obtaining information, and make the game experience smoother.

4.2 Enhance Interaction Smoothness

Personalized UI customization and interaction feedback optimization solutions have brought a brand-new experience to the interaction between players and the UI, greatly enhancing the smoothness of the interaction.

Personalized UI customization is like a game assistant tailored for players. Everyone's operation habits and visual preferences are different. The personalized UI is configured based on the player's historical operation data and visual habits. For players who are accustomed to operating with their right hand, place the frequently used operation buttons on the right side of the screen and adjust the size and spacing of the buttons to make them more in line with the operation range and force of the right hand. For players who are highly sensitive to colors, the color combination of UI elements can be adjusted to enhance visual recognition. For example, in a VR shooting game, players can set the weapon switching method, aiming assistance and other UI functions according to their own habits, making the operation more natural and comfortable.

The timeliness and clarity of interactive feedback are important guarantees for the smoothness of interaction. In the game, every operation of the player hopes to receive a timely response to confirm whether the operation is successful. Through eye-tracking feedback, when a player looks at an interactive UI element and performs an operation, the system will immediately provide visual, auditory or tactile feedback. For instance, in VR adventure games, when players select props through their line of sight and interact with them, the props will emit a visual feedback of flashing light, accompanied by clear sound effect prompts, allowing players to clearly know that their operations have taken effect. This clear feedback reduces the blindness of operations, enabling players to proceed with subsequent operations more confidently. The game process becomes smoother, further enhancing users' sense of immersion and participation, as if they were truly in the game world.

4.3 Reduce Visual Fatigue

Reasonable UI layout and visual design are the keys to reducing players' visual fatigue. The UI optimization scheme driven by eye-tracking feedback performs well in this aspect.

UI optimization based on eye movement tracking avoids the problems of overly dense and unreasonable distribution of UI elements. By analyzing the players' gaze data, developers can reasonably adjust the position and spacing of UI elements, making the players' gaze move more smoothly on the interface and reducing the burden of focusing and adjusting the eyes. For instance, in an AR strategy game, the various building ICONS and resource information that were originally densely arranged on the screen have been optimized and reorganized according to the movement pattern of the player's gaze. The spacing between the ICONS has increased, and the arrangement is more orderly. The player's eyes no longer need to frequently switch the focus among the dense elements, and visual fatigue has been effectively alleviated.

The dynamic UI display and hide mechanism also reduces the long-term occlusion of the game screen by the UI. In traditional VR/AR games, a large number of UI elements will always be displayed on the screen, blocking part of the game picture and affecting the visual experience

of players. Dynamic UI can timely hide unnecessary UI elements according to the game progress and the player's line of sight, allowing the player's eyes to enjoy a more complete game picture and get appropriate rest.

Personalized UI customization can also adjust the display effect of UI elements according to the visual needs of users. For players with poor eyesight, the font size can be increased. For players who are sensitive to color contrast, the color contrast between UI elements and the background can be enhanced. These personalized adjustments further enhance visual comfort, enabling players to enjoy the game for a longer time without feeling overly fatigued and to immerse themselves more deeply in the game world.

4.4 Enhance User Satisfaction

Taking into account the influences of the above several aspects, the UI optimization scheme of VR/AR games driven by eye-tracking feedback can significantly improve user satisfaction.

When players can obtain information more easily, interact smoothly and have a more comfortable visual experience in the game, their overall evaluation of the game will be significantly improved. Players no longer worry about the difficulty in obtaining information, no longer feel frustrated by the unsmooth operation, and no longer end the game early due to visual fatigue. They can focus more on the fun and challenges of the game and enjoy the immersive experience it brings.

This good gaming experience will prompt players to be more willing to spend time in the optimized game. They will log in to the game more frequently to explore more game content and gameplay. Meanwhile, players are also more likely to recommend this game to their friends and family around them, which is conducive to the word-of-mouth spread and market promotion of the game. A game with high user satisfaction can stand out in the highly competitive game market, attract more players, and bring greater commercial value and social influence to game developers.

5. Challenges and Response Strategies During the Implementation of the Optimization Plan

5.1 Technical Challenges

Eye-tracking technology itself has certain limitations, such as insufficient accuracy and being greatly affected by environmental light. This may lead to the accuracy of eye movement data being affected, and thereby influence the effect of the UI optimization plan. To address this challenge, developers need to select high-quality eye-tracking devices and conduct thorough testing and calibration. Meanwhile, combined with other sensor data, such as head posture data, a comprehensive analysis of eye movement data is conducted to enhance the reliability of the data.

5.2 User Privacy and Ethical Issues

Eye-tracking technology involves users' visual information, which may raise concerns about user privacy and ethics. Developers need to strictly abide by relevant laws and regulations. When collecting and using users' eye movement data, they should clearly inform users of the purpose and scope of data usage and obtain users' explicit consent. Meanwhile, effective data encryption and secure storage measures should be adopted to protect users' privacy and security.

5.3 Development Cost and Cycle

Introducing an eye-tracking feedback-driven UI optimization solution may increase the development cost and cycle of the game. Developers need to invest more resources in technology research and development, UI design and testing. To control costs and cycles, a modular development approach can be adopted, where the eye-tracking function is developed separately from other game functions and gradually integrated and optimized. Meanwhile, make use of the existing development tools and frameworks to improve the development efficiency.

6. Conclusion

The VR/AR game UI optimization scheme driven by eye-tracking feedback provides an effective way to solve the existing problems of VR/AR game UI. Through solutions such as UI layout optimization based on eye movement hotspots, dynamic UI display and hiding, personalized UI customization, and interaction feedback optimization, the user experience can be significantly enhanced, including improving cognitive efficiency, enhancing interaction smoothness, reducing visual fatigue, and increasing user satisfaction. However, in the process of implementing these optimization plans, challenges such as technology, user

privacy and ethics, development costs and cycles are also faced. Developers need to adopt corresponding coping strategies to overcome these challenges in order to optimize the UI of VR/AR games and improve the quality of the games. In the future, with the continuous development and improvement of eye-tracking technology and developers' in-depth understanding of user experience, UI optimization solutions driven by eye-tracking feedback will play a more important role in the VR/AR gaming field, bringing users a more high-quality and immersive gaming experience.

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