The Causes and Design Solutions of Mobile Vertigo in VR Games

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Abstract. With the development of the Internet, Virtual Reality (VR) games have become an important direction of the entertainment industry, but mobile `vertigo has always been the core bottleneck restricting its popularity. By analyzing the sensory conflict between visual input and vestibular feedback, this study aims to address the long-standing discomfort issue in VR gaming experiences. This paper takes three representative VR games, half-life: Alex, Ancient Scroll 5VR and Starcatcher, as the research object, focuses on the mainstream mobile interaction mode, and uses the comparative analysis method to systematically explore the vertigo risk and experience differences of different mobile modes, in order to find more comfortable and landing mobile design ideas. The research shows that the progressive ladder mobile system can effectively alleviate vertigo, improve users' willingness and experience, and provide reference for the optimization and development of VR game design. Future research will further integrate eye tracking data to build personalized adaptation strategies for different user groups.

Keywords: Sensory conflict, step-by-step guidance, visual field modification, eye tracking

1 Introduction

According to the data, the market size of China's virtual reality industry is expected to reach 5.66 billion yuan this year, and 2016 is generally recognized as the first year of Virtual Reality (VR) industry in the industry. After years of technology iteration and market cultivation, the focus of the virtual reality industry has long been away from the early single hardware equipment development, and has shifted to high-quality content creation and ecological improvement. With the unique experience of immersion and strong interaction, VR games have become the core track of the virtual reality industry layout. The market has shown a good momentum of vigorous growth, and has also become the key carrier to promote the popularization of virtual reality technology.

With the rapid iteration of Extended Reality (XR) games and immersive interactive experience, mobile vertigo has gradually become a key pain point hindering the further development of the industry. In the scene of free mobile VR game, the virtual space motion perceived by the player visually conflicts with the actual static state perceived by the vestibular system, which leads to dizziness, nausea, fatigue and other discomfort

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symptoms. This perception contradiction not only greatly reduces the user's sense of experience and the length of stay, but also seriously restricts the large-scale promotion and commercialization of free mobile XR content. For this common problem in the industry, the academic community has carried out many targeted explorations, which has laid a solid theoretical foundation for solving the problem of mobile vertigo in VR games. Palmisano et al. Explored the relationship between the type of display delay and the degree of VR vertigo from the technical level of the device, and made it clear that delay fluctuation is an important technical factor that aggravates user discomfort [1]; Hein et al. From the perspective of individual physiological differences, confirmed that people susceptible to motion sickness are also more prone to VR vertigo in reality, providing a reference for personalized experience design [2]; Palmisano team further verified through experiments that the deviation value of virtual and physical head posture can effectively predict the risk of vertigo, providing a theoretical basis for the establishment of vertigo early warning mechanism [3]; Babaita and others focused on the presentation form of VR content, compared and analyzed the difference in the incidence of vertigo between 360 ° panoramic content and conventional interactive content, and optimized the content design idea [4]; Teixeira et al. Built a DVP model to realize the quantitative prediction of VR vertigo probability, and promoted related research from qualitative analysis to quantitative research [5]. Although the existing research has analyzed the causes and influencing factors of VR vertigo from the multi-dimensional aspects of technology, individual and content, there is still a large research gap in the systematic optimization and targeted design of the mobile mode of VR games.

Based on this, this paper will systematically sort out the causes of VR game mobile vertigo, combined with existing research results, conduct a comprehensive analysis of the current mainstream VR game mobile mode, extract the defects and optimizable links of various modes, and then put forward practical design improvement countermeasures. This study aims to alleviate the dizziness and discomfort of players by optimizing the mobile mode design, improve the overall interactive experience and user willingness of XR games, provide theoretical support for the improvement of VR game interactive design, and help the virtual reality game industry achieve more sustainable development.

2 The Core Principle of Mobile Vertigo in VR Games

In the past seven days, the popularity of VR games on major mainstream platforms has exceeded 300000. With its revolutionary immersive interactive experience, VR games have received extensive attention from the industry and users [6]. However, the product has not yet achieved market penetration that matches its volume. User survey feedback shows that most players will encounter physiological discomfort such as game vertigo in the process of playing, which directly leads to the difficulty for players to maintain a long-term game experience, and even forced to interrupt interaction. It can be seen that the contradiction between the need for high-precision interaction and the

physiological endurance of players has become the core crux restricting the large-scale development of the VR industry.

In order to solve this core problem, the paper should first analyze the essence of vertigo. Huang Jie, deputy chief physician of otolaryngology surgery in BenQ Hospital Affiliated to Nanjing Medical University, said that the essence of vertigo stems from the perceptual conflict of the human balance triple system: vision, proprioception and the body position information transmitted by the vestibular organs of the inner ear to the central nervous system do not match, leading to abnormal brain judgment. In VR games, players only receive motion stimuli at the visual level, while the body is actually in a static state. The information conflict between vision and body perception causes brain processing disorders, and eventually induces discomfort symptoms such as dizziness and nausea [7]; At the same time, operations such as 360 degree rotation of the head and rapid speed change of the picture in the VR scene will further aggravate the perception conflict and the dizziness reaction. In addition, visual problems such as insufficient picture frame rate, motion blur, visual field distortion, auxiliary design problems such as scene closure, fast angle switching, and individual differences such as car sickness constitution of players will also affect the degree of vertigo.

To sum up, the core inducement of vertigo is the perception imbalance between visual perception movement and brain judgment. Overcoming this problem is the key research direction of VR game design and popularization.

3 Comparative Analysis of Mainstream VR Mobile Interaction Modes

3.1 Fast Move

Aiming at the mobile vertigo problem of VR games, the current mainstream game products have put forward corresponding optimization schemes. Half life: Alex, as a representative work adopting the fast-moving mode, enables the player to directly reach the target position through the instant transmission mechanism, effectively avoiding the physiological discomfort caused by the continuous displacement process. This mode has a low risk of vertigo, because it omits the intermediate movement link, reduces the interference caused by the high-frequency shaking of the lens, makes the player's visual perception and body state feedback tend to be consistent, and can significantly alleviate the vertigo reaction caused by continuous movement.

3.2 Smooth Movement

Ancient scroll 5 VR" uses a smooth moving mode to support players to achieve continuous perspective change and realistic movement in the game, with a strong sense of immersion and immersive interactive experience. This mode adds the field of view mask design in the process of rapid movement, which weakens the dizziness caused by large-scale movement to a certain extent, and has been widely recognized by players while taking into account the immersion experience. But even after optimization, the smooth movement mode is still the movement mode with the highest risk of vertigo. Affected by the change of continuous angle of view, the motion state perceived by the

player's vision has a significant conflict with the static state of the body fed back by the vestibular system and proprioception, which is very easy to cause the player's strong dizziness and discomfort.

3.3 Instant Steering

The star catcher adopts the instantaneous turning mode, and players can complete the turning operation by jumping from a fixed angle of view. The core feature of the instant steering mode is that it can switch the viewing angle at a fixed angle, which can effectively reduce the dizziness and discomfort caused by the continuous viewing angle rotation compared with the smooth steering. However, there is still a certain risk of vertigo in the instant steering mode. Although this mode replaces the smooth steering with a fixed angle jump, which reduces the conflict of sensory information to a certain extent, the player will still have a more fragmented sensory experience due to too fast long-distance visual angle displacement. At the same time, the flickering picture caused by continuous jump may also cause players' eye fatigue and discomfort.

3.4 Skill/Mechanism Substitution

The star catcher also uses the skill/mechanism substitution movement mode to replace the traditional smooth movement with skills such as blinking, sprint, hook and lock, so as to realize the displacement of players in the virtual scene. The risk of vertigo in this mode is relatively low, and its core mechanism is to compress the continuous movement process through skill movements, so as to effectively reduce the sensory conflict between visual perception, vestibular system and proprioception; At the same time, the player's autonomous and controllable movement rhythm not only inherits the comfort advantages of the fast movement mode, but also retains the high immersion characteristics of the smooth movement mode.

From the perspective of design logic, the skill/mechanism substitution mode reconstructs the basic movement logic based on functional skills, which alleviates the dizziness symptoms caused by continuous movement of players to a certain extent. At the same time, it expands the interaction level through differentiated skill actions such as "sprint and blink" and "hook up", and maintains a strong substitution experience while improving the fun of playing and the cool feeling of operation.

4 Adaptive Law

4.1 Analysis Conclusion

Through the comparative analysis, it can be seen that although the smooth movement mode has a strong sense of substitution, it has a significant dizziness reaction and is not suitable for long-term application in the game; The operation of the fixed angle instant steering mode is relatively smooth and natural, but if it is operated continuously in a large range in the later stage, the dizziness and discomfort of players will be aggravated due to the screen flashing problem; The fast moving mode weakens the continuous displacement process in the smooth movement, effectively weakens the physiological discomfort caused by the movement by locking the angle of view and improving the

movement speed, while retaining a certain movement process, avoiding the continuous flashing problem in the blinking mode; The skill/mechanism substitution mobile mode focuses on strengthening the sense of substitution of players, and its highly autonomous operation logic is more suitable for long-term play in the later stage of the game, with no obvious dizziness reaction, and can significantly improve the fun of the game.

4.2 Basic Design Mobile Process

At the advanced transition level, players can follow the path of gradual transition from smooth movement to Teleportation (BLINKING) mode: first adapt to the straight-line walking operation, and then gradually master the turning and complex movement in the battle scene. Specifically, in the early stage of VR game experience, players who pursue a high sense of substitution can be attracted by a smooth mobile mode to help them gradually adapt to the game style and walking logic - through low-speed, short-distance straight-line movement exercises, players can be familiar with the operation rhythm of handle control and visual angle linkage. At the same time, with the visual guide line, ground texture and other elements in the environment, the risk of spatial perception confusion can be reduced, and players' adaptation to the body feel of VR games can be improved; With the accumulation of game duration, a variety of mobile modes will be gradually introduced to strengthen the operation confidence and experience of players, reduce the trigger probability of motion sickness, and enrich the overall game experience. Figure 1 shows the linear progressive process of the stepped VR mobile system. (see Fig. 1)

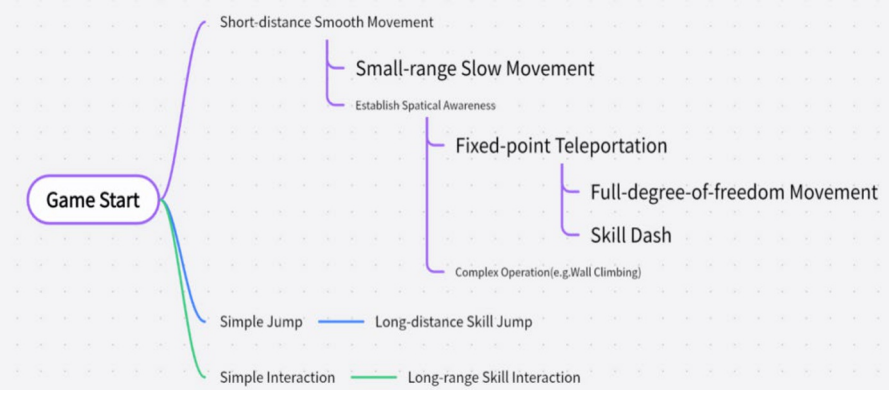

Fig. 1. ladder type VR mobile system · linear progressive flow chart. (Picture credit: Original)

Alt Text for the figure: A linear progressive flow chart of a ladder-type VR mobile system, starting from "Game Start" and branching into three main categories: movement modes (including short-distance smooth movement, fixed-point teleportation, full-degree-of-freedom movement, skill dash, etc.), simple jump (long-distance skill jump), and simple interaction (long-range skill interaction), with notes on spatial awareness and complex operations like wall climbing.

5 Design Method

5.1 Incremental Guidance

For the vertigo prone XR box court queer puzzle game, this study is based on the sensory conflict theory, combined with VR game cases and player experience feedback, this paper proposes a mobile system design based on progressive guidance, through the analysis and improvement of the mechanism of rapid movement, transmission, etc., to reduce the risk of vertigo and strengthen the game experience at the same time.

In order to clearly and intuitively show the advantages of this model, this paper will simulate the design and experience Optimization of a VR box court game mobile system based on gradual step-by-step guidance.

The design takes "skill growth" as the core logic, and decomposes the mobile mode into a four-level progressive system. Each stage pertinently adapts to the needs of players to adapt to the rhythm and game playing methods. In the introduction stage, only in the small-scale indoor tutorial scene, open the smooth and free movement of short distance and low speed, and help players quickly establish spatial cognition by relying on the realistic movement mechanism, laying the foundation for the subsequent complex mode; At the novice stage, unlock the short-range teleportation, and establish a spatial anchor through the landing point preview, handle vibration and sound effect prompt, so as to weaken the sense of spatial loss with the guidance of environmental vision; In the growth stage, with the progress of puzzle solving and battle, the paper will gradually unlock the directional sliding and rapid movement, synchronize the skill displacement with the advance of the plot, clarify the operation logic with the help of teaching animation, improve the adaptability of players' mechanism, bind the mobile mechanism with puzzle solving and battle depth, change the mobile from a simple tool to a core interactive skill, and gradually improve the operation comfort of players; At the proficiency stage, the user-defined mobile combination is opened, allowing players to connect a variety of mobile modes to form personalized paths. At the same time, the cooling mechanism is introduced to avoid excessive dependence on teleportation, encourage interaction with the environment to solve puzzles, and further weaken the separation of virtual and real perception.

In the game realization screen, the transition effect of fading in and out and differential tactile feedback are used to optimize the mobile experience, so that players can accurately perceive the motion state through tactile.

The design effectively reduces the sensory conflict between virtual movement and vestibular perception through a gradual step-by-step guidance strategy, and significantly reduces the probability of VR motion sickness; At the same time, skilled mobility has strengthened the exploration depth of the atrium world, improved the complexity of players' interaction, and provided a set of operable and landing practice paths for the optimization of the mobile mechanism and the improvement of user experience of VR games.

5.2 Visual Optimization

At the level of VR game design, visual optimization is one of the core links to alleviate mobile vertigo. First of all, people should avoid overly complex and elaborate visual

performance and redundant special effect rendering, give priority to ensuring that the game frame rate is stable at 90 hertz (Hz) or above, reduce the picture tearing and Caton phenomenon by optimizing the engine rendering pipeline and reducing polygon load, ensure the continuity and fluency of the player's visual experience, and weaken the vestibular visual conflict caused by picture jitter and frame rate fluctuation from the hardware level, so as to reduce the probability of dizziness [8].

Secondly, for the smooth movement link in the game, by adding the dynamic field of view mask design, the player's line of sight can be actively focused on the core target object, and the visual flow range can be consciously compressed to avoid the interference of edge distortion elements and fast flowing background on spatial perception during the movement process, so as to effectively alleviate the vertigo reaction of the player when the continuous angle of view changes. This design not only retains the immersion advantage of smooth movement, but also balances the physiological comfort through visual constraints, which can significantly improve the overall operation experience of the game and users' retention intention.

5.3 Scene Design

In the process of VR game scene design, open outdoor space should be selected as the main game scene to reduce the sense of oppression and space depression caused by closed and narrow environment, so that players can have interactive experience in a relatively loose and stable visual environment, so as to effectively reduce the dizziness and discomfort caused by the scene structure [9].

In the process of view switching and rapid continuous blinking, the transition effect of fade in and fade out can be used to weaken the abrupt feeling of scene and view switching, making the picture switching more gentle and natural. The design can reduce the impact of dramatic changes in visual signals on the perception system, improve the consistency and comfort of the player's visual experience, and further alleviate the dizziness caused by the rapid switching of viewing angles.

5.4 Eye Tracking

Eye tracking technology provides a physiological perception solution for the optimization of mobile vertigo in VR games. By capturing the user's gaze and attention distribution, dynamically adjusting the scene's visual parameters, realizing intentional movement and adaptive speed control, alleviating sensory conflicts from the source, providing an accurate and landing technology path for improving the comfort of the VR game's mobile mechanism [10].

In the framework of progressive step-by-step mobile mode proposed in this paper, the introduction of eye tracking technology can further improve the overall user experience comfort and adaptation efficiency. For example, in the free movement stage, the system can rely on eye movement data to capture the user's visual focus state, fixation stability and visual fatigue in real time, and then intelligently adjust the movement sensitivity, angle of view rotation rate and dynamic range of field of view, so as to realize highly personalized adaptive control. When the user's visual fitness is detected to be low, the system automatically reduces the moving speed and steering amplitude, weakening the visual motion intensity; When users gradually adapt to the virtual environment, they will moderately improve the mobility and enhance the

freedom of exploration on the premise of ensuring comfort. This method can effectively alleviate the sensory conflict in the process of gradual guidance, reduce the occurrence of motion sickness, and make the switching of mobile mode more natural and smooth.

6 Research Achievements and Future Prospects

6.1 Advantage Analysis

The progressive step-by-step mobile mode designed in this study uses a phased, low load, adaptive guidance strategy to significantly alleviate the mobile vertigo of VR games from the source. This mode gradually opens mobile permissions, accurately controls scene complexity and exercise intensity, effectively reduces sensory conflicts and improves spatial adaptation efficiency. While ensuring a high sense of immersion, it significantly reduces the incidence of motion sickness, significantly improves user comfort and operation acceptance, and finally forms a landing and reusable VR mobile mechanism scheme, which provides high-quality practical reference for the optimization of similar game mobile systems, and promotes the upgrading of VR interactive experience to a more comfortable and humanized one.

6.2 Challenges and Prospects

Although this progressive step-by-step mobile mode effectively alleviates the mobile vertigo of VR games, there are still challenges to be optimized in practical application. The coordination and dynamic switching strategy of multiple mobile modes is not yet mature, which is easy to interfere with the operation adaptability of players; The adaptability of mobile mode to the scene environment lacks systematic verification, and scene switching may cause visual fragmentation and vertigo; At the same time, the deep integration of mobile mechanism and game content, and the multi-objective balance of operating comfort and immersion still need to be further explored.

In response to the above challenges, future research will focus on multi-mode mobile collaborative optimization, scene mobile interaction adaptation design, and the integration of mobile mechanism and content [11]. Through iterative optimization and user experiments, the robustness and universality of the scheme will be improved to provide support for the upgrading of VR game interactive experience.

7 Conclusion

This study confirmed that the information imbalance between vision and body perception is the core cause of mobile vertigo in VR games, and there are significant adaptation laws between different mobile interaction modes and players' adaptation process. The proposed strategies of progressive guidance and visual optimization can effectively balance immersion and comfort. This research makes up for the blank of VR game mobile vertigo operation scheme, and provides a direct reference for the development of most VR game mobile systems. However, there are still challenges in the collaborative connection of mobile mode, optimization of scene adaptation and deep

integration with game content, which requires continuous iterative optimization in subsequent research. In the future, quantitative research can be carried out around the individual differences of players, aiming at the details of mobile design and the overall structure of the game, combined with emotion capture, biofeedback and other technologies, to achieve dynamic relief of dizziness, improve the comfort of players, and further promote the development of VR games.

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