Research Article

Immersive animation scene design in animation language under virtual reality

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Abstract
The study aims to explore a new form of immersive animation scene design and improve the application effect of virtual reality (VR) in immersive animation scene design. First, the research status of VR and the related concepts of animation scene design are analyzed, and the basic characteristics of visual effects in immersive VR animation scenes are summarized. Second, three elements to create immersion in a VR animation scene are color, light and shadow, and digital information technology. Finally, the application of VR technology to an animation scene design is analyzed, the problem of vertigo caused by VR animation scenes is deeply discussed, the vertigo test process in an immersive VR scene is proposed, and an experiment is designed to verify it. The results show that in the design of an immersive VR scene, the relative moving speed of the forward straight line should be maintained less than 6.5 times of the audience's perceived speed, and the optimal relative moving speed of the scene should be maintained below 5 times of the audience's perceived speed when they moving backward. In the design of a rotating animation scene, the long-term high-speed rotation should be avoided. If there must be a rotating scene, the rotation speed should be as low as 50°/s. The research provides some guidance for the application of VR to immersive animation scene design.

Article highlights

- This study discusses immersive animation scene design from dizziness prospective. It is novel.
- This study introduces relative motion perception illusion and use displacement velocity and relative displacement to analyze VR vertigo.
- Len motion is divided into forward and reverse linear, horizontal and vertical rotation and camera center rotation to study vertigo source.
- The dizziness evaluation model is designed and combined with the virtual indoor scene developed to achieve a visual immersion experience.

Keywords Virtual reality · Animation scene design · Immersion · Animation language · Dizziness test

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1 Introduction

With the progress of society, people's spiritual requirements become higher and higher, entertainment requirements, information requirements, knowledge requirements, aesthetic and their spiritual requirements mainly have excitement requirements, leisure and requirements, and thinking requirements. Under this circumstance, all industries tend to use various new digital media technologies to meet people's spiritual needs, and the animation industry is no exception [1]. The animation industry also tries to apply emerging technologies to make their animation works give their customers a better experience. And a reasonable animation scene design is a key to improving customers' experience. Narrative research in virtual reality (VR) animation is available to multiple disciplines [2]. It involves the application of computer technology, artificial intelligence (AI), sensor technology, and display technology. In mixed media and technology, immersive VR scene design, as an important direction of future artistic creation, attracts more and more attention.

There are many studies on VR, which are carried out in different fields. Qian et al. used VR in clinical practice and created a gastroscope simulation system with a VR simulator to capture anatomical details in response to mass production of traditional equipment [3]. Using VR in clinical practice can overcome the shortcoming of the traditional clinical surgery and make students practice in the process. The immersive animation scene is also designed using the technology. McCarthy and Martin designed a VR diving system, which creates a fully animated 2.5-dimensional environment, guiding participants under the limited time instead of providing an interactive experience. This method maximizes the immersion space of the underwater environment and make the divers have the experience close to non-divers [4]. The design of the immersive animation scene draws lessons from the above diving system. Zhang studied the influence of animation visualization methods in the embedded system in kindergartens on the confidence and ability of animation teachers [5], which realizes quantitative exploratory design and pays attention to quantitative collection and analysis. The embedded system is used to create and use the VR animation visualization system for early review of the images before service. The results show that students' self-efficacy scores improve significantly over time. Horst et al. studied the application of asymmetric VR, which is an important subclass of multi-user VR and provides all participants with the same interaction possibility [6]. For example, in an educational scene, learners can use immersive VR to understand themselves in different exhibitions in the virtual scene and educators can use PC to track and guide learners through virtual exhibitions, and know about the security risks in the real world.

In summary, the relevant research focuses on assisting students' in their study and improving tourists' experience, and paying attention to the practicability and functionality of products. The innovation is to enhance the immersion sense by using 3D technology. Moreover, the causes of dizziness in 3D animation are discussed, the immersion test process is put forward, and the measures to reduce dizziness and the scene design requirements for 3D animation are found to reduce the dizziness of specific people to 3D animation.

Based on the above analysis, VR is applied to immersive animation scene design to improve make customers have a better experience of animation works. First, the related concepts of animation scene design are introduced, and the basic characteristics of visual effects in the immersive VR animation scene are summarized. Three elements to create an immersive VR animation scene are color, light and shadow, and digital information technology. Finally, the application of VR to animation design is analyzed, hoping to improve the technicality and experience of the immersive animation scene design via VR.

The organizational structure of this study is as follows:

Section 1 introduces the research background, significance, purpose and research status of related fields. Sect. 2 introduces the theoretical methods and models used, including the overview of animation scene design, the basic characteristics of visual immersion, the way to create immersion, the establishment of the VR dizziness and fatigue model and the experimental design process. Section 3 mainly carries out statistical analysis and fitting on the experimental results, and compares and analyzes the vertigo results of forward linear motion VR scene, backward linear motion VR scene, and horizontal, vertical, and central rotation, and draws conclusions. Section 4 summarizes this study's research content and innovation points, discusses the corresponding deficiencies that need to be improved in this research work, and makes prospects for future research directions.

2 Theories and methods

2.1 Overview of animation scene design

The design of an animation scene is the initial step of creating animations according to the animation plot. The scenes that do not exist in reality are created in combination with users' imagination, and they should fully meet the development requirements of animation plots [7, 8].

Animation scene design can provide the animation director with goal planning, role settings, and space, and present the artistic style and taste of the whole work.

Animation language, also known as animation lens language. Lens language is to use the lens head to express the meanings. Generally, the intention of the photographer can be observed from the picture taken by the camera [9].The things that the photographer wants to express are acquired from the change of the subject and picture. Although the expression of lens language is different from that of ordinary speech, their functions are the same. Therefore, lens language has no rules. As long as you use lens to express your intention, this can be called lens language no matter what method you use [10].

Lens language uses pictures and sounds to convey the author's intention to the audience. The audience doesn't respond very much to most shots [11]. But when a classic or touching shot appears, the audience may show their excitement. In other words, it is difficult for lens language to have two-way communication with the audience directly. Language cannot directly show the form of a specific thing, but it can reflect specific characters and things in animated films. Therefore, lens language is actually a language form based on pictures. Compared with daily oral expression, lens pictures are clearer. The audience can have direct contact with the people and things in the film without intermediary.

Images in lens language always come from the real world, and they are displayed in the picture and replace reality through certain means. Lens language has the function of magnifying some attributes of real things. Animated films also have this role. In addition, they also have the virtuality of films. Compared with the real language system, lens language contains different elements. It doesn't have tones and words, but has scenes and colors. These elements are independent and interact with each other to compile the information that lens language wants to express. Lens language can also extend thoughts through the picture, present infinite possibilities and richness to the film, reproduce the real scene with complex and colorful language expression, and add flexible and rich thoughts and feelings to make the audience feel the implied meaning of the picture.

For each shot, a specific scene is needed for the performance of the character. The scene where the plot takes place is called an animation scene [12, 13]. An animation scene is a specific space developed according to the overall artistic style and story plot. This space is continuous and divided into interior space, exterior space, and the combination of interior and exterior space. And the details are shown in Fig. 1.

The scene designed can be presented by the plot of the animated film. If necessary, it can also be reflected through the lens and the emotional and psychological reactions of the characters, forming a unique expression form of the lens language. It enriches the expressiveness of the plot and improves the story-telling ability and the visual effect of the animated film.

2.2 Basic characteristics of visual immersion effects

VR is a new way for people to visually process and interact with complex data via computers. Compared with the traditional man–machine interface and popular window, VR has made progress in technology. "Reality" refers to any thing or environment existing in the world in the physical or functional sense. "Virtual" means the virtual environment created by computers. In the sense, VR is a special environment generated by computers. People can "project" themselves into this environment by using various special devices, and control the environment to achieve specific purposes.

VR animation has a complex system with a real-time 3D computer graphics technology, wide-angle stereo display technology, human body tracking technology, tactile/force feedback, stereo, network transmission, voice input and output and other technologies. It has three characteristics: (a) immersion. It is realized by the three-dimensional images of computer graphics software to immerse people in a virtual environment and have the same sensory experience in a real and objective world; (b) interactivity. In this virtual environment generated by computers, people

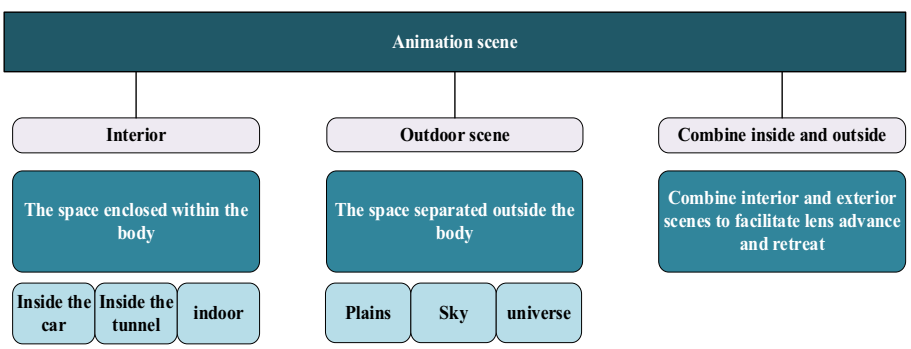

Fig. 1 Composition of an animation scene

can use some peripheral sensing devices to act objects in the simulated environment and obtain corresponding feedback; (c) conceptuality. The virtual environment created by VR is the restoration of the known world and the wonderful presentation of the unknown world.

Immersion is an art form developed in recent years. It makes the viewers have a fresh and interesting experience, so it is given much concern. And the immersive art forms can enrich people's cultural and entertainment life, diversify art design methods, and expand the size of the audience.

From the text level, things and artistic works with immersive text labels can arouse consumers' curiosity, including the immersive secret room escape, immersive experience, and immersive viewing [14]. Immersion can enhance the sense of expectation and has a certain virtual effect. It plays its role by using human perception and cognition to create a virtual world so that the experimenter has the feeling of being in the virtual world. As a basic part of modern science, philosophy, and technology, virtual immersion can give people an illusion and an unprecedented experience, and convey emotional characteristics more vividly than any other media.

2.3 Immersion creating forms in animation scene design

There are many elements in the dynamic scene design, and the main elements to create immersion in animation scenes are color, light and shadow, and digital information technology. First, color plays an important role in animation scene design [15]. The rational use of the emotional characteristics of color in sports scenes can cause strong emotional and psychological state changes of the audience and make them feel they are there personally. Color is also important and has a positive effect on feeling the emotion of animation scenes [16]. The designed scenes are designed by color processing, decomposition, and combination. Through the careful arrangement of animation types, styles, and colors, the audience can more strongly and intuitively experience the emotions of Van Gogh's inner world.

Colors need to be processed subjectively by designers. In the process of design, artistic expression forms can be created freely and subjective initiative should be played fully to complete modeling design, scene design, action design, and color design until scripts and themes are created jointly. Emotional changes can be presented by symbols, which is an effective way to display the aesthetic, spatial, and visual effects of dynamic scenes. The special story atmosphere provides an excellent foundation for entertainment and animation production, emphasizes the excellent visual effect of the scene, and shapes a better character.

The second is the ingenious use of light and shadow. Light is the basis for giving things shape and color. All visual feelings are closely related to light. Light produce Shadows can be produced by the different light shootings. The influence of light on the shape and color of objects directly affects the psychological mood of the audience.

Light and shadow are important factors that determine the visual style of a dynamic scene, and they can tell the story. Modern animation scenes pay more attention to light and shadow to achieve the best visual effect. Light and shadow in the dynamic scene can imitate those in the real world, and reflect them quickly in the dynamic scene naturally, showing the rich and subtle changes of the real world.In the design of animation scenes, making full use of the effects of lights is an important skill that animation designers must acquire.

The third element is the application of digital information technology [17]. The use of 3D virtual painting technology in animation works gives new life to the designers of animation scenes. This technology changes the method of creating 2D spatial graphics on papers, provides the 3D spatial canvas for creators, reinterprets the old rules of spatial perspective, and expands the imagination of designers. In 3D painting space, you can create three-dimensional lines and colors and create paintings personally. 3D virtual paintings help designers to create a virtual world with their own internal logic [18, 19]. The development of technology does not change the principle of paintings but improves working efficiency. In addition, the creation of VR cinema and television also becomes the focus of industrial applications. Hardware devices are constantly developing and gradually becoming mature, but there are still many unknowns about how to create a VR cinema and how to define the creating content because there are no clear technical standards or artistic rules for VR shooting, transfer, or production. The lack of high-quality VR film and television content is a serious problem restricting the development of the industry. Two main factors affect the movie viewing experience.One is too strong immersion, which makes the audience feel dizzy and fatigued, affecting their viewing experience, and the other is whether the audience's attention is concentrated on the scene instead of the story to be told. In response to the above problems, an evaluation method of films and television programs is proposed and the evaluation model is implemented. The model can condense the rhythm and significant characteristics of the film and television program into a VR environment and evaluate them.

2.4 Implementation of virtual reality dizziness and fatigue model

VR dizziness appears with the development of VR equipment. The earliest research focuses on immersive simulators used by automobiles, aircraft, and other projects. Therefore, the symptoms of dizziness in equipment are also called simulator motion sickness, which is caused when the user reproduces the virtual environment in hardware, such as a flight simulator or driving simulator. Early studies of motion sickness symptoms in simulators do not include the influence of visual perception. In early times, researchers believe that dizziness is a common symptom.

The researchers compared the dizziness with the illusion and found that the illusion is one of the causes of dizziness. With the development of VR equipment, the illusion is increasingly regarded as an essential part of simulating a virtual environment. In training, rehabilitation, treatment, and other projects in the VR environment, self-practice plays a vital role. According to research, illusion increases the expressiveness of a VR environment. When illusion and motion sickness caused by vision are compared, due to the limitation of equipment, the "vector drum" is used for simulation. The device is rotatable and vertical cylindrical, and its interior is decorated with texture maps, in which the main body is sitting inside.

People's illusion is mainly reflected in two aspects, namely relative displacement speed and relative displacement direction.

The judgment of the displacement speed has nothing to do with the movement. For example, if an aircraft travels a long distance at high speed and a nearby car travels a relatively short distance at a relatively low speed, the observer will feel that the speed of the moving car is higher than that of the aircraft. For the observer, the observation distance determines the influence of the angular velocity of the object on the observer's perception of velocity. In a VR environment, the observer's cognition of the real world will be disturbed. In a large enclosed space, the observer cannot effectively feel the real speed of the object when it is moving inside. For the viewer, if the object on the screen moves at the same speed in the same time unit, the object 5 m away from the viewer will move 10 m and the object 10 m away from the viewer will move 20 m. If there is no occlusion and the moving objects are projected on the screen with similar size, the observer will feel that the moving speed of the two objects is the same, that is, binocular parallax will be generated.

2.5 Design of the experiment based on virtual reality

A test framework of VR film and television dizziness is proposed to enhance the audience's immersion experience. The specific test structure is shown in Fig. 2.

The test is classified. In VR movies, the lens is completely different from the traditional lens. In the motion scene, the audience has a similar feeling after the angle is rotated. If the scene is moving when the viewer watches with VR devices, the moving speed of the ordinary plane is faster. When the moving object in the photo moves at a speed greater than 20°/s, people will feel uncomfortable and difficult to adapt to it. When the speed of the object exceeds 80°/s, this will cause great discomfort to people. In a VR environment, with the increase of the moving speed of the scene, the viewer tends to watch the moving object with a slow-moving speed, and adjust the view field to the same motion axis as the direction. However, in real-world tests, users usually reduce body rotation as much as possible based on the user's positive axis according to the current motion. And the phenomenon that

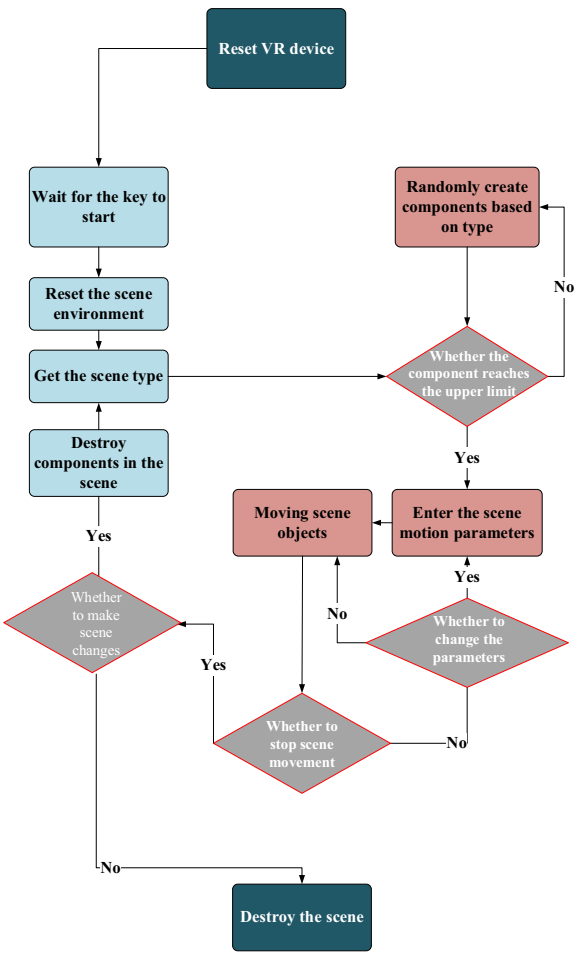

Fig. 2 Immersive VR dizziness test

the direction is opposite to the direction of travel arises. Generally, lens motion is divided into forwarding linear motion, reverse linear motion, horizontal camera rotation, vertical camera rotation, and camera center rotation. Two scenarios are tested for each motion situation. The test procedure is recorded at the actual moving speed of the scene. For the circular channel, the actual motion distance parameter is the linear motion distance, which can be approximated by the specific directivity, recording method, and the linear motion corresponding to the linear motion. Since there is no visual difference in the rotation of the environment, the recorded data are the rotation angular velocity of the actual overall environment [20].

The rating classification of VR dizziness symptoms is shown in Table 1 below.

The dizziness evaluation coefficient is calculated by Eq. (1).

$$V_x = \frac{\sum_{n=1}^{N} V_{nx}}{N} \tag{1}$$

In Eq. (1), V_{nx} represents the subject's dizziness at x.

At present, the main users of VR equipment are young people, and there are differences in dizziness among different ages and genders. The age range of subjects is 20–30. Within this age range, the user's sensitivity to dizziness is relatively stable and has a certain tolerance to the symptoms.10 males and 10 females are selected to make the research conclusions more reliable and universal so that the final results are not affected by gender inequality.

3 Results and discussion

3.1 Dizziness degrees of virtual reality scene moving forward in a straight line

Through the analysis and statistics of the data of linear channel and circular channel in the forward linear motion scene, the final results are shown in Fig. 3.

Figure 3 shows that the dizziness of the audience under the straight channel and the curve channel is similar, and it is concluded that the two channels can provide a consistent experience. If the relative movement speed of the

Table 1 Rating classification of VR dizziness symptoms

Feeling level	Very comfortable	Comfortable	Barely comfortable	Uncomfortable	Unbearable
Symptom description	The scene feels good and can be viewed naturally	The scene movement is obvious, but it does not cause trouble	The scene movement is significant, which will affect the viewing, but it is within the acceptable range	Scene transition speed is too fast, causing dizziness	Can't stand the scene at all, trying to stop watching
Rating level	1	2	3	4	5

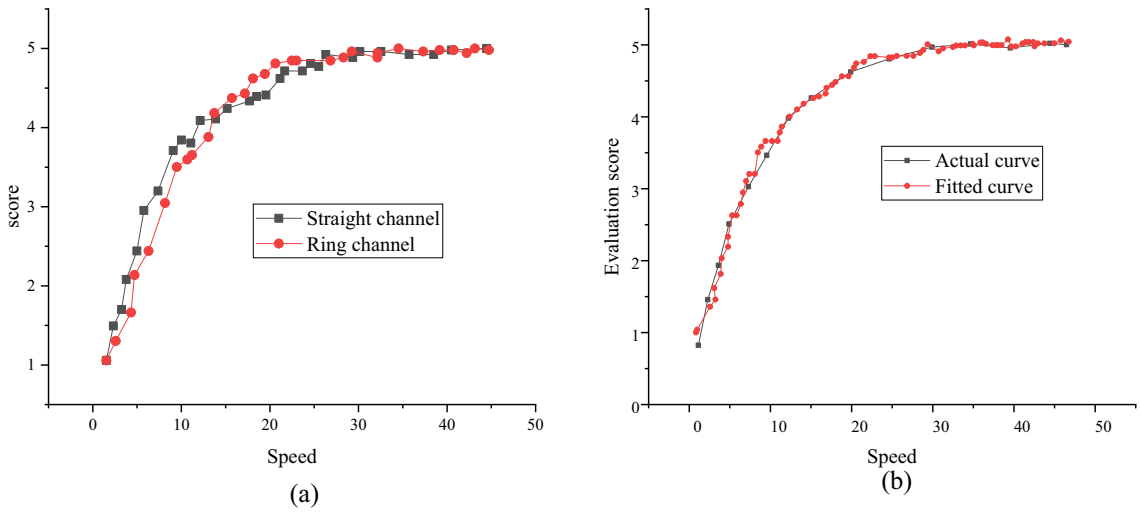

Fig. 3 Dizziness of VR scene moving forward in a straight line (**a** the comparison results under the scenes of the straight-line channel and curve channel; **b** the curve fitting results)

scene is slow, that is, when the motion speed exceeds 6.5 times that perceived by the audience, the motion speed is almost linear. If the relative speed of the scene exceeds 6.5 times, the audience will gradually feel uncomfortable and have some dizziness symptoms.

3.2 Dizziness of virtual reality scene moving backward in a straight line

Through the analysis and statistics of the data of linear channel and circular channel in the backward linear motion scene, the final results are shown in Fig. 4.

Figure 4 shows that the comparison results are more consistent with Fig. 3. The dizzy experience of the audience under the straight channel and curve channel is similar. Therefore, it can be concluded that the straight channel and curve channel have little impact on the dizziness of the audience. If the relative movement speed of the scene is slow, that is, when the motion speed exceeds 5 times that perceived by the audience, the motion speed is almost linear. If the relative motion speed exceeds 5 times, the audience will gradually feel uncomfortable and have some dizziness symptoms. In the backward motion scene, if the relative speed of the object exceeds 18 times, the audience will be unbearable. Because both forward and backward linear movements are uniform, it is found that in the process of backward linear movement, the audience's tolerance of dizziness is lower than that of forwarding linear movement, making them feel dizzy easily.

3.3 Dizziness degrees in the horizontal rotation motion scene

Through the analysis and statistics of the data of linear channel and annular channel in the horizontal rotation motion scene, the final results are shown in Fig. 5.

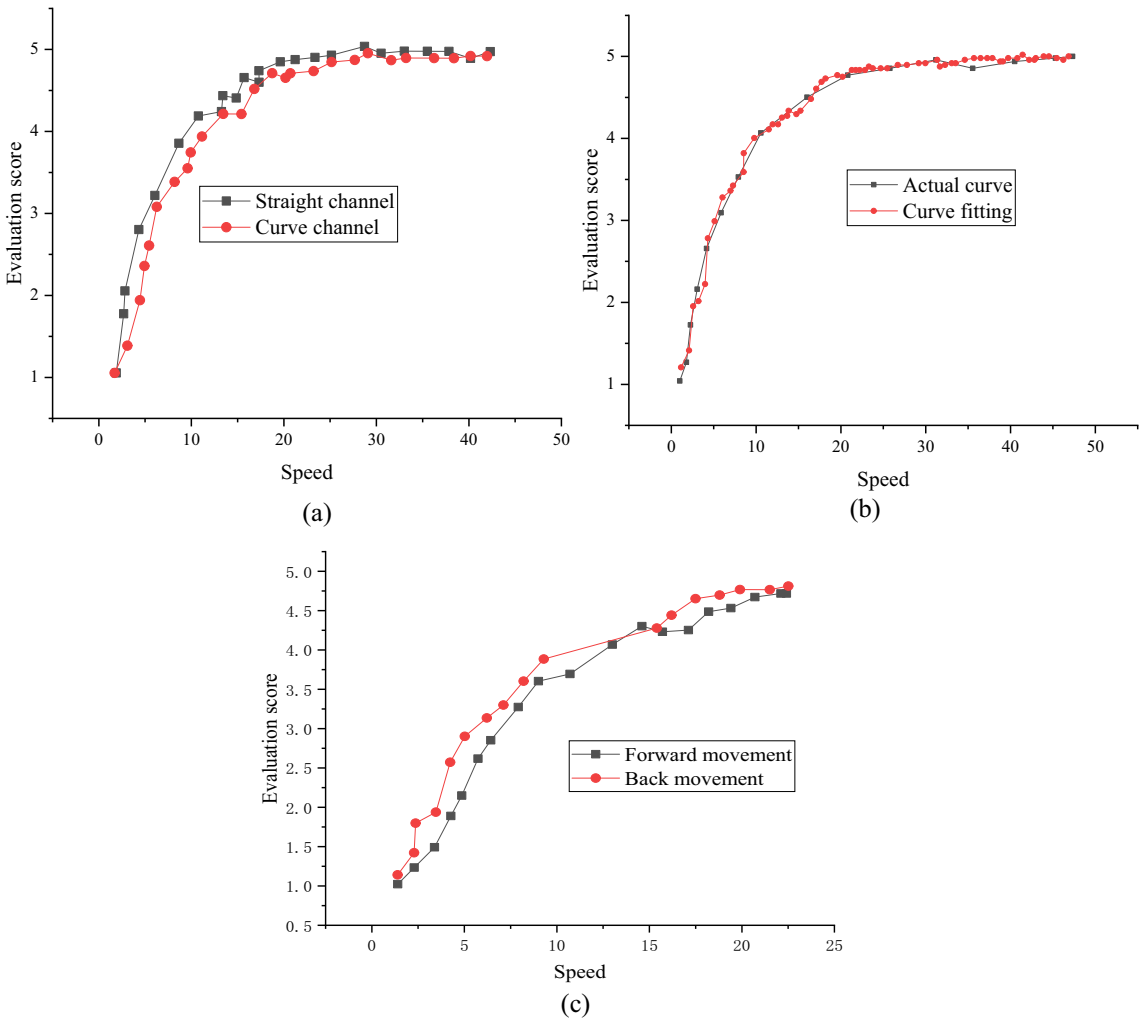

Fig. 4 Dizziness of VR scene moving backward in a straight line (**a** comparison results under the straight-line channel and curve channel; **b** curve fitting results; **c** comparison of the fitting curves of moving forward and backward)

Figure 5 suggests that since the environment content is independent of the environment rotation, the two scenes are regarded as two groups of the same type, and the results are exponentially weighted. The results show that when the rotation speed is less than 50°/s, it has a linear relationship with the audience's motion score index, and its growth rate is large. Within 50°, 2 dizziness degrees are added. However, the dizziness degree is less than 3 degrees within this range, which is low and within the range acceptable to the audience. When the rotation speed exceeds 50°/s, the audience begins to have dizziness symptoms. The dizziness exceeds 2, but the growth rate gradually decreases. If the rotational angular velocity exceeds 125°/s, the dizziness reaches level 4 and the audience can stand the basic dizziness. When the rotation angle speed exceeds 200°/s, the dizziness is stable at level 5, and the audience cannot stand it at all.

3.4 Dizziness degrees in the vertical rotation motion scene

Through the analysis and statistics of the data of linear channel and annular channel in the vertical rotation motion scene, the final results are shown in Fig. 6.

Figure 6 shows that the dizziness experience of the audience under the straight channel and the curve channel is similar, so it is concluded that the results of the two channels are consistent. If the rotation angle speed of the scene is slow, that is, when the rotation angle speed is less than 45°/s, the relations between the audience's dizziness and the rotation speed are linear. If the rotating angle speed of the stage exceeds 45°/s, the audience will gradually feel uncomfortable and have some dizziness symptoms. If the rotating angular speed of the stage exceeds 120°/s, the audience will have a strong sense of discomfort.

3.5 Dizziness degrees in the central rotation motion scene

Through the analysis and statistics of the data of linear channel and annular channel in the central rotation motion scene, the final results are shown in Fig. 7.

Figure 7 shows that if the rotation angular speed of the scene is slow, that is, when the rotation angular speed is less than 50°/s, the relations between the audience's dizziness and the rotation speed are linear. If the rotating angular speed of the stage exceeds 50°/s, the audience will gradually feel uncomfortable and have some dizziness symptoms. If the rotating angular speed of the stage exceeds 275°/s, the audience will feel strongly uncomfortable and try to escape from or destroy the scene. Since horizontal rotation, vertical rotation, and central rotation belong to rotational motion, the fitting curves of the three groups are compared, and it is found that the audience's tolerance range for each rotation is within a certain range. In the process of scene adaptation, when the rotation angle speed gets fast, all viewers will have a strong sense of dizziness. In addition, the discomfort caused by dizziness will continue for some time. In this situation, designers should avoid rotating scenes with a long time or high frequency when designing animation scenes.

In short, the dizziness of the audience in the VR animation scene is analyzed. The results show that in the design

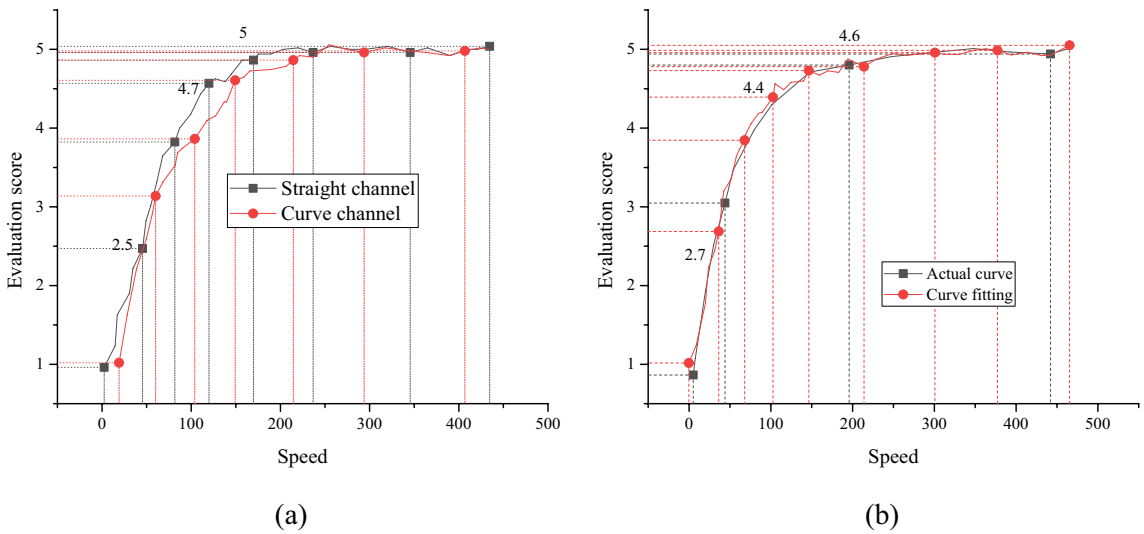

Fig. 5 Dizziness in the horizontal rotation motion scene (**a** comparison results in the scene of the linear channel and curve channel, **b** curve fitting results)

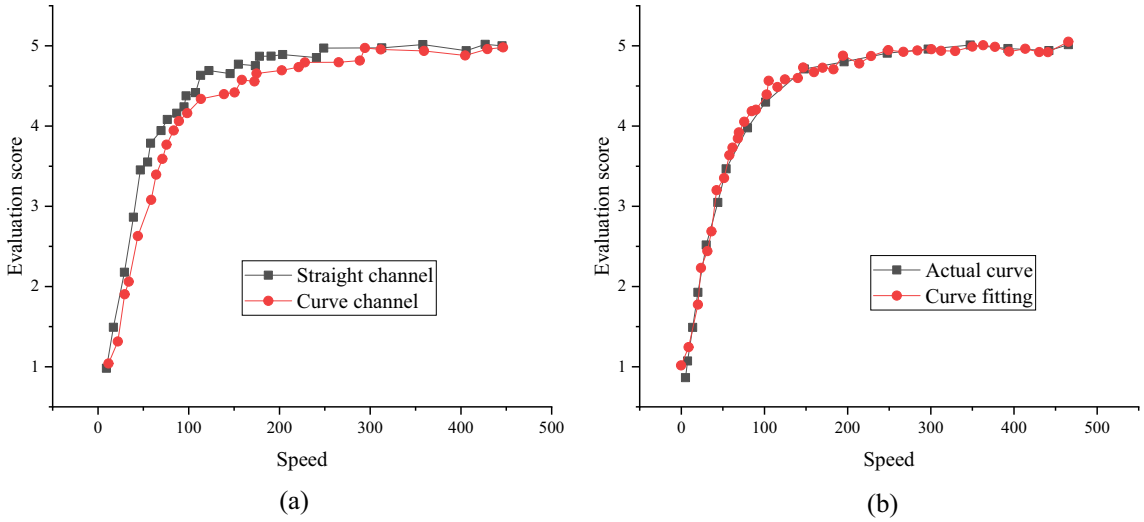

Fig. 6 Dizziness in the horizontal rotation motion scene (**a** comparison results in the scenes of the linear channel and curve channel; **b** curve fitting results)

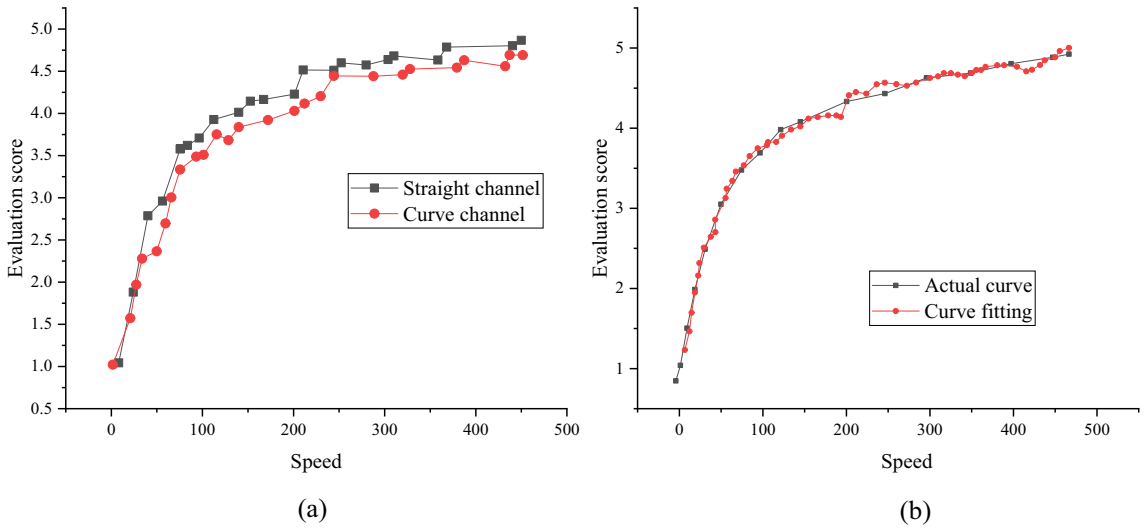

Fig. 7 Dizziness degrees in the central rotation motion scene (**a** dizziness comparison results in the scene of the linear channel and curve channel; **b** curve fitting results)

of the animation scene, the VR animation designer should maintain the forward linear relative moving speed of the scene less than 6.5 times of the audience's perceived speed, and maintain the optimal relative moving backward speed of the scene less than 5 times of the audience's perceived speed. In the design of rotating animation scenes, the long-term high-speed rotation should be avoided. If there needs a rotating scene, its rotation speed should be as low as 50°/s.

The study of human perception of vertigo under the conditions of forward linear motion, reverse linear motion, horizontal camera rotation, vertical camera rotation and camera center rotation will help VR animation designers to set appropriate motion scenes and scene moving speed when designing animation scenes. It can avoid causing strong discomfort to the audience. Shan and Wang proposed a film and television animation design method based on 3D visual communication technology. Film and television animation videos were collected through 3D visual communication content production, server processing and client processing, and animation video images were conveyed through splicing, projection mapping and texture synthesis of animation video image frame [21]. Compared with the research here, its design of animation images only stays on 3D images, and its effect on animation immersive experience is not as good as this study.

Yang designed animation scenes through the spatial relationship between film and television animation, creating atmosphere, highlighting characters, scene scheduling in the scene, and visual effects [22]. This study is to create immersion in color, light and shadow and digital information technology, which have some similarities. Li et al. used real-time computer graphics technology, 3D modeling technology and binocular stereo vision technology to study multi-view animated character objects in VR technology, and designed a binocular stereo vision animation system [23]. In contrast, this study not only designs the immersive animation scene, but also analyzes the human perception of vertigo under various conditions of VR technology, which provides a great reference value for the design of VR immersive animation scene.

4 Conclusion

The application of VR technology to immersive animation scene design is studied. Then, the basic characteristics of visual effect immersion in VR animation scenes are summarized. Three ways of creating immersion in animation scene design are analyzed. Aiming at the problem of dizziness of the audience on VR animation, an immersive VR dizziness test process is proposed to reduce the audience's discomfort. The experimental results show that the relative moving speed and rotation speed of the virtual animation scene can be controlled to reduce the audience's discomfort and improve the level of immersion. 3D technology is used to improve VR animation, improve users' sense of immersion, and provide a new idea to improve immersive VR animation in the future. The expected research results have been basically achieved. However, the research work still has the following deficiencies. Research materials of VR technology are scarce, so in the future, attention will be paid to the impact of color and light and shadow transformation on the audience's sense of experience. This experiment focuses on economic benefits without considering the running speed and system safety, which will be optimized in the future.

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Declarations

Conflict of interest There are no confict to declare.

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