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Research on the Application of VR Technology in the Simulation Training of Sanda Actual Combat Scenarios

Yun Wu, Kunhua Zheng, Lingqian Fu

Jiangxi Science and Technology Normal University, Nanchang 330038, Jiangxi, China

Abstract: Addressing the limitations of traditional Sanda training, this study thoroughly explores the application prospects of VR technology. Based on constructivism, flow theory, and embodied cognition, a VR Sanda training system is constructed to provide a safe, controllable, and highly realistic training environment for Sanda, promoting the transformation of Sanda training mode from "experience-led" to "technology-empowered," and offering new insights for the innovation of competitive sports training models.

Keywords: VR technology; Sanda; Actual combat scenario simulation; Training system

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1. Introduction

In 2018, the Ministry of Education issued the "Educational Informatization 2.0 Action Plan," aiming to implement the spirit of the 19th National Congress of the Communist Party of China, promote "Internet + Education," and accelerate educational modernization [1]. In the same year, the Ministry of Industry and Information Technology issued guidance documents, focusing on promoting the development of "VR+" [2]. In October 2021, the General Administration of Sport of China issued the "14th Five-Year Plan for Sports Development," which clearly proposed to promote the development of emerging sports such as virtual sports and implement the "Sports+" project [3]. As an advanced simulation technology, virtual reality can virtualize things that are difficult to present intuitively in the real world and display them vividly in a three-dimensional manner, bringing users an immersive experience. As a product integrating traditional Chinese martial arts and modern competitive sports, Sanda faces problems such as the risk of injury due to physical confrontation in actual combat and poor training effectiveness. Based on this, this study aims to analyze the application prospects of VR technology in the simulation training of Sanda actual combat scenarios, hoping to provide theoretical support for the in-depth application of VR technology in competitive sports.

2. Overview of Virtual Reality technology

Virtual Reality (VR) technology is a computer simulation system that can correspond and integrate the "real world" with the "virtual world." Scholars generally consider this technology to be the third fundamental method for humans to understand the objective laws of nature, following mathematical reasoning and scientific experimentation. Its main characteristics are immersion, interactivity, multi-perceptivity, imagination, and autonomy [4]. The key technologies include: (1) dynamic environment modeling technology; (2) real-time three-dimensional graphics generation technology; (3) stereoscopic display and sensor technology; (4) application system development tools;(5) system integration technology [5].

3. Theoretical basis for virtual scenario construction

3.1. Constructivism learning theory

Constructivism learning theory is a theory related to knowledge and learning, proposed by J. Piaget *et al.* based on cognitive processing theory [6]. The constructivist view of knowledge holds that the construction of knowledge relies on diverse environments, and knowledge itself is not a direct reflection of the real world, but rather an interpretation and hypothesis of phenomena [7]. Therefore, when facing different environments, learners should rely on their existing knowledge and experience to construct knowledge meaningfully, thereby forming a new understanding of knowledge.

3.2. Flow theory

Flow Theory, also known as Immersion Theory, refers to the deep state of immersion and joyful experience felt when an individual is fully engaged in an activity, reaching complete focus and immersion [8]. Flow experience is characterized by a balance between challenge and skill, clear goals, immediate feedback, the merging of action and awareness, complete absorption, a sense of control, the loss of self-consciousness, and intrinsic motivation [9]. Therefore, to effectively apply flow theory, attention should be paid to the interaction between students' immersive experience and time limits of the game, enabling learners to achieve a state of deep learning while effectively preventing and controlling the phenomenon of game addiction.

3.3. Embodied cognition theory

Embodied cognition theory emphasizes the important role of bodily experience in the construction of knowledge and meaning. Unlike traditional teaching, which focuses on the role of the brain in the learning process, embodied learning theory advocates for the "whole person," including the body, emotions, senses, and mind, as the medium of learning, and emphasizes the "physical aspect" in meaningful activities [10]. Therefore, teachers should make full use of the multimodal field of the body to create new teaching meanings through encoding, decoding, understanding, transformation, and recording.

4. System module design and development

4.1. Virtual scenario system module design

The module design adopted by the VR Sanda training system includes four core functional modules, with the technical implementation and cognitive training logic as follows:

(1) System Navigation Module

The system navigation module serves as the entry point for user-system interaction, enabling users to initially interact with the system through handheld controller operations. This module employs a three-level navigation hierarchy (main menu - mode selection - difficulty grading), combined with visual focus guidance technology and haptic vibration feedback mechanisms, ensuring that users' spatial orientation and decision-making in the virtual environment align with the requirements of cognitive load theory.

(2) Multimodal motion acquisition module

The multimodal motion acquisition module integrates motor skill learning theory to construct an educational system based on the three-dimensional aspects of vision, kinesthesia, and audition. It demonstrates standardized movement trajectories through video, highlights the technical characteristics of Sanda, explains key technical points synchronously through voice, and uses text prompts to focus users' attention on the key and difficult points of the movements, thereby reinforcing users' motion cognition.

(3) Hierarchical defense training module

Based on the progressive principle of skill transfer, the hierarchical defense training module is designed with two differentiated sub-modules: (A) Structured combination practice mode: For example, a fixed attack sequence of left jab, right cross, left roundhouse kick, and right cross is preset. The module uses a recurrent neural network to control the action rhythm of the virtual character, enabling users to develop a conditioned reflex mechanism for defensive movements. (B) Dynamic adaptive mode: This mode employs a deep reinforcement learning framework, allowing the virtual character to dynamically generate attack commands based on probability models and behavior tree algorithms, making its action combinations capable of simulating the unpredictability of real combat scenarios.

(4) Training data visualization

Based on big data analysis technology, the system constructs an evaluation index system that includes dimensions such as movement fluency, reaction time, and defense success rate. It also utilizes the Unity 3D engine to generate a heatmap of defense blind spots and produces a diagnostic report on skill weaknesses, providing data support for training optimization.

4.2. Development platform for the virtual scenario system

Unity Technologies, as an industry benchmark for cross-platform game development engines, features technical architecture with ecological compatibility and development friendliness. Unity's engine employs a modular compilation system, and its development environment supports both Windows and macOS operating systems, while also offering multi-terminal compilation and adaptation capabilities, allowing for one-click generation of localized executable files for mainstream platforms such as Windows, Mac, and Android [11,12]. Unity 3D supports multi-paradigm programming languages such as C# and JavaScript. Among them, C#, with its object-oriented design and efficient exception handling functions, forms a deep synergy with Unity's entity component system. Its simple operation interface and personalized settings greatly save development time and costs [13].

4.3. Diversified tactical scenario design empowered by VR technology

In Sanda's actual combat training, the cultivation of tactical decision-making ability and on-site adaptability relies on a complex and changeable confrontation environment. This can be achieved by constructing a three-dimensional tactical space using VR technology, thereby realizing diversified tactical simulations. During the construction of the virtual space, actual combat scenarios with different terrains are simulated. The physical

engine performs real-time calculations of the center of gravity shifts of the human body, forcing athletes to adjust their movement strategies. Additionally, environmental interference simulations, such as flashbulb disturbances and increased audience shouting, are used to enhance the athletes' environmental perception threshold.

5. Analysis of the application of VR technology in the Sanda actual combat scenario training

5.1. Teaching material analysis

The Sanda course textbook is a specialized Material designed for Sanda teaching in universities. It typically includes the basic theories, technical key points, training methods, and competition rules of Sanda. It provides students with a systematic and comprehensive learning resource, helping them receive comprehensive training and improvement in Sanda. However, the slow update speed of the textbook may lead to a mismatch between the teaching content and the development of Sanda, and the lack of actual combat cases in the textbook is not conducive to students' understanding and application. Therefore, the application of VR technology in the Sanda actual combat scenario simulation training can provide students with a new training method.

5.2. Analysis of student conditions

As one of the traditional martial arts in China, Sanda is rich in cultural connotations and practical value. The goal of the Sanda course is to teach students basic Sanda techniques, improve their physical fitness through training, enhance their self-protection abilities, and cultivate brave, confident, and tenacious personality traits. College students are in the late stage of adolescence, with their physical development basically mature, and they are full of energy, with high levels of physical fitness and athletic ability [14]. Given the confrontational nature of Sanda, students must learn how to effectively avoid injuries during the learning process, as well as strategies for protecting themselves while respecting their opponents in actual combat. Confrontational training and competitions may trigger psychological barriers such as fear and tension in students, which not only affect the normal performance of techniques but may also diminish their enthusiasm for learning [15]. Therefore, integrating virtual reality technology into the teaching of Sanda courses can provide students with a safer and more controllable learning environment, effectively reducing psychological barriers, improving learning efficiency, and enhancing actual combat skills.

5.3. Analysis of teaching objectives

(1) Knowledge and skill objectives

Through learning, students will master the basic theoretical knowledge of Sanda, including technical key points, tactical applications, and rule understanding. They will also learn to use VR equipment for Sanda actual combat simulation training, thereby improving their observation, judgment, and reaction abilities in actual Sanda combat.

(2) Process and method objectives

Through VR simulation training, students can experience different actual combat scenarios, enhancing their situational adaptability; cultivate students' ability to analyze opponents' movements and formulate tactical strategies in the VR environment; thereby strengthening students' technical application and tactical execution abilities in actual combat.

(3) Affective attitude and values objectives

Cultivate students' courage and confidence in facing challenges, reducing tension and fear in actual combat training. Emphasize the spirit of sportsmanship during the learning process, cultivating students' values of respecting opponents and fair competition. Through teamwork and communication, enhance students' sense of collective honor and team spirit.

5.4. Analysis of teaching key points and difficult points

(1) Teaching key points

This course is dedicated to creating highly realistic combat scenarios, ensuring that students can obtain an experience similar to actual matches in the VR environment. In addition, the teaching process will focus on guiding students on how to correctly use and operate VR equipment, enabling them to train in a safe environment and flexibly apply Sanda techniques in different VR simulated scenarios.

(2) Teaching difficult points

Students' adaptability to VR technology, especially the sense of immersion and realism in simulated combat, is crucial. Therefore, the teaching process needs to focus on the fine-tuning of Sanda technical movements to ensure the accuracy and fluency of execution. Through the cultivation of psychological qualities in actual combat, students can overcome nervousness and fear in confrontations. By constructing a teaching evaluation system, a scientific system can be established to objectively and effectively evaluate students' performance and progress in VR Sanda actual combat simulation training.

6. Conclusion

VR technology, with its characteristics of immersion, interactivity, and multi-perceptivity, breaks through the limitations of traditional Sanda training, providing athletes with a safe, controllable, and highly realistic training environment. Through the design and development of modules such as virtual scenario construction, multimodal action learning, hierarchical defense training, and training data visualization, it can not only improve the scientificity and safety of training but also inject new momentum into the sustainable development of Sanda.

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