Research on police physical training based on virtual reality technology

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Abstract: With the acceleration of science and technology innovation, Virtual Reality technology (VR) has been widely used in many fields. At the level of police physical training, VR provides technical support for the innovation of traditional training mode by virtue of the characteristics of environmental simulation, process controllability and risk avoidance. This study focuses on the practical application of VR technology in police physical training, and systematically demonstrates its technical adaptability, implementation path and optimization direction. Analyze its technical advantages, specific application methods, as well as the problems and challenges faced in this field. The research shows that the technology can effectively simulate the actual combat environment, promote the coordinated development of the stress response and psychological adjustment ability of the trainees, and reduce the

equipment loss and time cost, which has important practical value in promoting the modernization of the police training system.

1 Introduction

As the key executive body of the social security system, the police department puts forward compound requirements for practitioners' physical quality, professional skills and psychological ability to withstand pressure. The current trend of intelligent and dynamic development of crime forms makes the traditional training system present significant limitations when dealing with the new law enforcement needs. Physical training as a basic part of police capacity building, the conventional mode relies on fixed venues and standardized equipment to carry out basic training[1] such as strength and speed. The research shows that there are two dilemmas in this kind of training: First, situational simulation training is limited by the singularity of pre-set scenarios, and police officers are prone to disconnection between physical fitness and technical and tactical application when dealing with sudden and high-risk police situations; Second, site-dependent training is faced with resource allocation problems, which are not only subject to objective conditions such as weather and time, but also have training cycle fluctuations and security risks, which may indirectly affect the efficiency of police resources. Taking specific high-risk police scenes as an example, the established training methods are difficult to reproduce the physiological and psychological stress and tactical coordination requirements in real law enforcement environments, which restricts the conversion efficiency of actual combat capabilities.

The intervention of virtual reality technology provides a breakthrough path for the above difficulties. The technology constructs a realistic law enforcement scene through 3D modeling and sensor feedback, realizes the dynamic interaction and data backtracking in the training process, improves the training immersion, and provides a quantitative basis[2] for the formulation of personalized training programs. Virtual reality technology has the characteristics of immersion, interaction and controllability, and can realize multi-sensory integration and dynamic interaction in a highly simulated physical environment, so as to create an immersive environment for users, make up for the disadvantages of traditional

training such as situation diversity and poor real-time feedback, and provide more targeted training modes and systems for police. From the technical point of view, virtual reality technology has the following advantages in police physical training: 1) it can build a highly simulated situation environment; 2) multi-dimensional real-time interaction and feedback; 3) With high safety and low risk; 4) Economical and exp[3]andable. From a practical point of view, in the field of military training, virtual reality technology has been applied in foreign countries more mature, the relevant units use VR technology to train soldiers to adapt to the battlefield environment, which greatly improves their psychological ability to withstand pressure and strain[4]. However, in the field of police training, China is still in the initial stage, although some relevant departments have used VR technology to conduct special training on subjects such as capture and combat, anti-terrorism and emergency response, and have achieved certain results. However, due to the high technical cost, lack of content development and limited popularity, the potential of virtual reality technology has not been fully tapped.

To sum up, the application of virtual reality technology in police physical training has important theoretical significance and practical value. On the one hand, the advantages of VR technology in high-complexity situation simulation provide an effective solution to make up for the deficiency of traditional training; On the other hand, the real-time feedback and data collection function significantly improves the scientific and personalized level of training, and can better meet the actual needs of modern police work. This study intends to systematically explore the application path of virtual reality technology in police physical training, and deeply reveal its technical advantages, practical results and existing challenges through theoretical analysis, case study and effect evaluation, aiming to provide important references for the optimization and innovation of police physical training system.

2 Overview of virtual reality technology

Virtual Reality (VR) is a kind of human-computer interaction technology system based on computer simulation. Its core feature is to build an immersive virtual environment through multi-modal perception reconstruction. By integrating multi-sensory channels such as vision, hearing and touch, the technology realizes the dynamic interaction between users and virtual scenes, thus breaking through the limitation[5] of physical space.

Virtual reality technology is mainly composed of hardware equipment, software system and interactive interface. In terms of hardware, Head-Mounted Display (HMD) is the basic display terminal of virtual reality, which realizes the user's three-dimensional immersive

viewing through stereoscopic vision and high-definition display. The motion capture system is the main way of virtual reality interaction, tracking user actions through sensors, and mapping to the corresponding virtual environment, to achieve user dynamic interaction; Force feedback equipment simulates human touch, pressure and other senses to enhance the reality of the virtual environment[6]. In terms of software, virtual reality relies on graphics rendering, real-time computing and data processing technologies to produce realistic dynamic environments and ensure real-time user interaction. In addition, virtual reality relies on high-performance computers and strong algorithms to complete the real-time calculation and processing of complex scenes and multi-dimensional data. In recent decades, virtual reality technology, with the support of hardware performance and graphics, has been gradually applied in military, medical and education fields. In the military field, virtual reality uses complex battlefield images and real-time data to simulate commanders' tactical training and simulation exercises, such as flight simulator and tactical simulation system[7]; In the medical field, virtual reality through pre-recorded surgical scene simulation operation teaching, combined with rehabilitation training, and according to the data feedback to improve the medical staff's operation skills[8] in the virtual environment; In the field of education, the three-dimensional immersive teaching environment created by virtual reality makes learners' spatial perception richer and more interactive, and learners can master more learning skills and improve learning efficiency[9]. These successful practical cases provide a reference for the application of virtual reality technology in police physical training.

3 Demand analysis of police physical training

As a key component of police work, police physical training aims to improve the physical quality, practical skills and psychological quality of police, so as to cope with the changeable and complex working environment[10] more effectively. At present, police physical training faces the following main demands and challenges:

3.1 The overall improvement of physical fitness

Police work has multi-dimensional physical requirements for practitioners, and needs to establish a balanced development model in terms of strength, endurance, flexibility and sensitivity (see Table 1).

Strength quality: As the physiological basis of adversarial law enforcement, it is necessary to focus on the development of core muscle group and explosive power, but the current training lacks a targeted load control mechanism;

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Endurance level: long time duty execution requires good aerobic metabolism capacity, while conventional training is insufficient in the scientific ratio of intensity and duration;

Sensitive coordination: The ability to quickly change direction and jump obstacles is the key to cope with sudden police situations, but the standardization of training content is low, and the consideration of individual differences is insufficient.

3.2 Scenario adaptation requirements of actual combat training

The uncertain characteristics of police work require the training system to have a high degree of situational restoration ability. However, traditional training has the following limitations:

Single scene: it is difficult for fixed sites and preset scripts to simulate the dynamic changes of the real law enforcement environment, resulting in a disconnect between the training effect and the actual demand;

Lack of psychological stress: routine training lacks psychological adaptability training to high-pressure situations, which affects the quality of on-the-spot decision-making of law enforcement personnel;

Lack of teamwork: the handling of group incidents requires efficient tactical cooperation, and the existing model has limited support for multi-person collaborative training.

3.3 Economic optimization needs of training effectiveness

Resource constraint is an important factor restricting the sustainable development of police training, which is mainly reflected in:

Strong site dependence: outdoor training is restricted by weather, time and other external conditions, which affects the continuity and stability of the training plan;

High equipment loss rate: high-intensity confrontation training leads to the consumption of protective gear, equipment and other materials too fast, increasing operation and maintenance costs;

High time cost: the traditional mode requires a lot of manpower input, and the training effect evaluation lacks quantitative basis, which affects the efficiency of resource allocation.

Table 1. Demand classification and optimization direction of police physical training

Demand dimension	Training objectives	Limitations of traditional mode	VR technology optimization path
Strength quality	Enhancing adversarial law enforcement capabilities	Inaccurate load regulation	Real-time force feedback and dynamic resistance regulation
Endurance levels	Increased ability to sustain duty	The intensity ratio is not scientific	Personalized cardio training regimen
Sensitive coordination	Improve the ability to respond to emergencies	Low level of standardization	Multi-dimensional motion capture with pose correction
Mental quality	Strengthen resilience to high-pressure environments	Lack of stress scenarios	Immersive situational simulation and physiological monitoring
teamwork	Optimize the efficiency of tactical coordination	Lack of cooperative training	Multiplayer virtual scene interaction

Virtual reality technology provides a systematic solution to the above needs. By building a highly realistic training environment, VR technology can realize dynamic adaptation and personalized customization of training scenes, improve training effects, and significantly reduce resource consumption and security risks. This technology-enabled training mode provides a new possibility for the modernization transformation of police physical training. The research shows that the efficiency of knowledge transfer is enhanced through multi-sensory stimulation in the immersive learning environment, and the learning effect is increased by more[11] than 40%.

4 The application of virtual reality technology in police physical training

4.1 Immersive scene simulation

The application of virtual reality technology (VR) in police training has significant advantages, especially in its ability to construct highly realistic, immersive training scenarios. This technological breakthrough offers a whole new dimension to police training, enabling the creation of simulated environments that are highly similar to, or even exactly consistent with, actual work situations (Table 2).

Table 2. Classification and technical implementation of virtual reality training scenarios

Type of scene	Technical characteristics	Training objectives	Core equipment
City Hunt	Dynamic path planning, Multiple target tracking	Improve environmental adaptation and 3. Ability to target	VR headsets, Location base station
Indoor assault	Space acoustic simulation, Tactical decision support	Strengthen team collaboration with Tactical execution	Force feedback gloves, Collaborative system
Field search and rescue	Terrain generation algorithms, Biometric signal recognition	Enhanced endurance with Sense of direction	Omnidirectional treadmill, Physiological monitor
Group incident handling	Group behavior simulation, Emotion recognition	Improving risk assessment vs Emergency decision making	Eye tracking device, Environmental simulators

Compared with the traditional training mode, virtual reality technology overcomes the limitations of site conditions, cost input and scene design, and changes the traditional mode limited to basic and fixed situations. By introducing dynamic characters, interactive items and real-time changes of the environment, virtual reality can simulate various emergencies in the real scene to the greatest extent. It fully reflects the diversity and unpredictability in actual

police practice. For example, the simulation of extreme events such as violent conflicts, hostage taking, natural disasters and terrorist attacks can enable police to face the complex and dynamic situations they may encounter in their daily work in a virtual environment, thus effectively improving their emergency response ability and tactical decision-making level[12]. This immersive experience not only stimulates the trainees' interest in learning, but also greatly improves their resilience and decision-making efficiency in the face of complex tasks. In addition, the immersive characteristics of virtual reality enable the police to deeply experience the situational pressure during the training process. For example, in the simulated scene of pursuing suspects on foot, the environmental variables such as the interference of pedestrians and vehicles, the influence of day and night conditions, the flight speed of law enforcement objects and the change of direction are superimposed, which is fully consistent with the high risk and high energy consumption of such police situations in reality. It not only strengthens the physical strength of the trainees, but also greatly enhances the psychological quality of the police. Through repeated training, it can effectively improve the law enforcement ability of the police to cope with high pressure environment in actual combat, so as to ensure the efficient completion of the task objectives.

4.2 Motion capture and refined training

Virtual reality technology combined with motion capture system provides highly personalized and refined training programs for police physical training, which significantly improves the scientific and practical effectiveness of training. In the traditional training mode, the police's action performance usually relies on the subjective evaluation of the instructor. Although this method is intuitive and easy to understand, it has obvious limitations in the accuracy of the action and the quantitative analysis of data. In contrast, virtual reality technology, through the use of wearable sensing equipment, records every minute movement of the trainee in real time and converts it into quantifiable data for analysis and feedback.

Specifically, through key data such as pace frequency, power output and body balance, the virtual reality system can provide personalized movement optimization suggestions for police officers to help them improve movement accuracy and physical performance[13] during training. This digitally-enabled training mode can not only accurately correct the irregular movements of the trainees, but also provide targeted optimization suggestions in a timely manner. For example, in the grappling confrontation training, the motion capture system can capture every offensive and defensive movement of the trainee, and conduct timely evaluation

combined with the dynamic behavior of the law enforcement object. This interactive dynamic feedback mechanism enables the police to get more accurate physical and skill integration training guidance in the virtual environment, so as to effectively improve the overall ability of actual combat.

Virtual reality technology can also generate a personalized training plan according to the individual law enforcement ability of the trained police, avoiding the phenomenon of "one-size-fits-all" in the traditional mode of training instructors, and truly "teaching according to their aptitude". By combining the training content with individual differences, police officers can participate in tailor-made training programs according to their own physical levels and training needs to ensure the maximum training effect. This technology has transformed police physical training from the traditional "experience-oriented" mode to "data-driven" precise training, further improving the overall efficiency and pertinence of training, and providing a more comprehensive and sustainable optimization path for the improvement of police physical quality.

4.3 Psychological stress training

Police officers face extremely high psychological pressure in their actual duty, especially when dealing with high-risk tasks such as violent conflicts, terrorist attacks and hostage incidents. At this time, the stability of psychological quality has a crucial impact on the effect of task execution. However, the traditional police physical training mainly focuses on the improvement of physical quality, and often neglects the cultivation of psychological anti-pressure ability. By simulating real high-pressure situations, virtual reality (VR) technology provides police with the opportunity to conduct psychological stress training in a safe and controllable environment, thus filling the gap of traditional training in improving psychological quality (Table 3).

Table 3. Psychological stress training module design

Training stage	Stress levels	Scene complexity	Goal achievement criteria
Beginner	low	Single target pursuit	Heart rate fluctuation ≤10%
Intermediate	In the	Multi-target	Decision accuracy ≥80%

Training stage	Stress levels	Scene complexity	Goal achievement criteria
Advanced	high	jamming Compound emergencies	Task completion time ≤ set value

In the virtual training scenario, the system can design a variety of psychological stressors, such as the simulation of real high-risk police situations, the random occurrence of emergencies and the change and interference of law enforcement environment. These scenarios can effectively simulate the emotional and cognitive pressure that police may encounter in actual combat, so that they can quickly improve their psychological anti-pressure ability when facing such challenges. In addition, virtual reality technology can also collect the psychological response data of the trainees in real time, including physical and psychological indicators[14] such as heart rate, breathing rate and emotional fluctuations. Through the analysis of these data, it can comprehensively evaluate the psychological adaptability and adaptability of police under high pressure environment. This data-driven evaluation method provides quantitative indicators of police psychological quality, effectively identifies the shortcomings in their psychological quality, and provides a scientific basis for personalized improvement. For example, in the training of simulated hijacking, the virtual reality system can gradually increase the complexity of the scene and situational pressure, help the police to carry out adaptive training under increasing pressure, and finally improve their decision-making stability and execution efficiency[15] under high pressure environment.

Virtual reality technology provides a brand new, data-driven training mode for police psychological quality training, which can help police effectively improve their psychological anti-pressure ability through highly simulated environment and real-time data analysis, and then improve their coping and decision-making level in complex and high-pressure situations.

4.4 Data analysis and personalized training

A significant feature of virtual reality technology is that it can collect and analyze training data in real time, and provide personalized training programs for police physical training based on these data. Specifically, the data analysis covers physical indicators (such as strength, endurance, flexibility, etc.), movement performance (such as movement accuracy,

speed, efficiency, etc.), and psychological states (such as stress level, attention distribution, etc.). Through the sensing equipment of the virtual reality system, these data can be accurately recorded and converted into quantitative indicators, providing detailed data support and scientific basis for the training process (Table 4).

Table 4. Diagram of police physical training based on VR technology

Training Module	Training objectives	VR scenarios and equipment	Training content and interaction design	Data monitoring index
Rapid response training	Improve your ability to respond to emergencies	Scene: Common police situation in the community (suspects resist or flee) equipment: VR headset, motion capture gloves, touch feedback vest	- Quickly identify danger and select (weapon, police weapon, bare hands) to control the suspect - Touch feedback simulates the impact of an attack	- Reaction time, decision accuracy, movement regularity
Endurance and cardiorespiratory training	Enhance cardiorespiratory function and sustained mobility	Scene: Virtual mountain forest, city chase equipment: VR headset, treadmill/stair, heart rate monitoring band	- Simulated pursuit mission: Adjust running speed according to terrain changes - combine virtual obstacles (climbing, jumping) to improve overall endurance	Heart rate, blood oxygen saturation, distance traveled, calories burned
Explosive power and strength training	Improve short-time explosive power and muscle strength	Scene: Virtual handling of the wounded, door breaking task equipment: VR headset, resistance rope,	- Simulate heavy lifting (casualty/equipment) - Trigger resistance feedback in virtual door breaking action	Peak force, time to completion, muscle fatigue

Training Module	Training objectives	VR scenarios and equipment	Training content and interaction design	Data monitoring index
Balance and coordination training	Improve physical coordination in complex environments	force feedback robot arm Scene: high-ceilinged single-log bridge, rocking platform equipment: VR headset, balance board, inertial sensor	- Maintain balance in the virtual high-altitude scene - avoid dynamic obstacles (such as landslides)	Balance stability, number of errors, multi-limb collaborative efficiency
Tactical synergy Training	Strengthen teamwork and tactical execution	Scenario: Hostage rescue equipment: multiplayer VR collaborative system, voice interaction equipment	- Perform tasks in different roles (commander, negotiator, assault team, sniper) - real-time voice communication and tactical adjustment	Team response delay, mission success rate, consistent command execution
Psychological stress training	Enhance mental stability in high-pressure situations	Scene: Explosions, gunfights, crowd disturbances Equipment: VR headsets, surround sound systems, environmental simulators (wind/heat)	- Complete instructions under noise, visual interference - simulate stress response training during sudden explosions	Heart rate variability, task completion, subjective stress score

Based on digital empowerment, virtual reality technology can provide a solid foundation for the development of personalized training programs. For example, through a comprehensive analysis of a trainer's performance in a specific scenario, the system can identify deficiencies in certain training areas (such as lack of endurance, slow reaction speed, etc.) and adjust the training content, intensity and focus accordingly, thus effectively making up for their shortcomings. This personalized training method helps police quickly improve their core abilities while avoiding the waste of resources and inefficiency common in traditional training modes. In terms of the improvement of training interest, the system's dynamic adjustment function enables the difficulty and pressure level of the training scene to

be flexibly adjusted according to the actual needs of the trainees, ensuring that the training always remains appropriately challenging and targeted. In addition, the high scalability of virtual reality technology provides strong support for the long-term tracking and optimization of training effects. The system can compare the data of multiple training horizontally and vertically to track the changing trend of police physical and psychological quality, so as to provide a quantitative basis for evaluating the long-term training effect. This kind of data-based refined training and continuous tracking not only improves the effect of a single training, but also provides an important reference for the police department to optimize the overall training system, so as to improve the comprehensive quality of the police team more efficiently.

To sum up, virtual reality technology supports personalized and dynamically adjusted training programs through accurate data collection and analysis, and promotes police physical training from the traditional experience-driven mode to the data-driven mode. This kind of data refined training method, combined with long-term effect tracking, not only improves the scientific and targeted training, but also provides a strong support for the optimization of police training system and the improvement of the overall quality of police.

5 Case analysis

5.1 Research and application at home and abroad

In recent years, virtual reality (VR) police training technology has gradually transformed from the field of theoretical research to the field of application, and has achieved significant results in many countries. Internationally, especially in Europe and the United States, virtual reality police training technology has been applied more and more widely, and many police departments in the United States have taken VR technology as a routine training project[16]. The Los Angeles Police Department (LAPD) has spent years building a virtual reality-based training system that can replicate a variety of high-pressure simulations, including violent crime prevention, terrorist attack response, hostage rescue and almost any other complex situation. Officers can run high-stress and high-stakes simulations in as many as 50 different scenarios. In surveys, police officers trained using virtual reality systems spent an average of 20 percent less time making decisions and reactions during training, were 15 percent less likely to make tactical mistakes, and were better able to handle stress. The Federal Bureau of Investigation has also installed virtual reality equipment at its training bases to train law enforcement officers to make the right decisions in situations and to use big data analytics to

further optimize police operations. The Metropolitan Police in the United Kingdom has also used virtual reality to train its officers on counterterrorism, and in a test simulating a terrorist attack on the London subway, more than 85 percent of officers detected the threat earlier in the second training session and reduced unnecessary action. The results not only show that VR technology can greatly improve the tactical quality of police officers, but also further reduce training consumption and waste through the same repeatable simulation of the scenario. In comparison with foreign countries, domestic virtual reality technology is also a new link in police training, and there are many cases of using this technology. For example, Chengdu Public Security Bureau has cooperated with a technology company to develop a set of virtual reality emergency response training system, which integrates advanced 3D modeling, motion capture and other technologies. Simulate large-scale mass incidents, emergencies and other scenes. The success rate of the police officers participating in the training in the simulated scene was increased by 20% compared with that before the training, and the satisfaction of the practicability and fidelity of the training system reached more[17] than 85%. The results show that the implementation of virtual reality technology in police situation handling training is relatively small in China, but this technology has great potential in the skills, tactical literacy, situation identification and other aspects of police situation handling.

To sum up, both at home and abroad, the research and application practice of virtual reality technology have shown its significant advantages in police training. Through virtual reality technology, the actual effect of police training has been significantly improved, and the dynamic optimization of training content can be supported by big data. Looking forward to the future, with the continuous introduction of technology and the promotion of independent research and development, China's police training system is expected to fully integrate virtual reality technology, so as to improve the efficiency and safety of the overall police work.

5.2 Effectiveness and challenges

The application of virtual reality (VR) technology in police physical training has begun to show results. VR technology has effectively improved the actual effect of training through highly simulated scene simulation. The police's reaction ability, decision-making ability and tactical execution ability in the virtual environment have been significantly enhanced. For example, by simulating complex situations, trainers were able to make decisions more quickly in high-stress situations such as group conflicts and violent incidents. A study of 100 police officers trained in VR showed that more than 78 percent of participants reported significant

improvements[18] in their emergency response and psychological resilience during real-world tasks. In addition, VR training significantly reduced the risks associated with traditional simulation training. For example, by holding and grappling training in a virtual environment, police officers can avoid physical injuries caused by confrontational movements, thus improving the safety of the training. However, although virtual reality technology has made initial achievements in police training, its widespread promotion and implementation still face many challenges. First, the high cost of technical equipment and development are major obstacles limiting its large-scale application. High-performance virtual reality equipment, such as head-mounted displays and motion-capture systems, are expensive, while the development and maintenance costs of specialized training software are also relatively high. This cost pressure, especially for police departments with limited budgets, is a significant constraint on the adoption of the technology. Secondly, the existing virtual reality training system still has shortcomings in content design. The setting of training scenes and tasks in some systems is too template, which fails to fully restore the complexity of actual police work, resulting in a certain disconnect between the training content and actual needs. In addition, police officers' acceptance and adaptability to new technologies also need to be gradually improved. In police departments where traditional training modes dominate, virtual reality technology may be questioned or rejected to a certain extent due to the complexity of operation and the innovation of training forms.

In view of the above problems, future research should first reduce equipment procurement and maintenance costs with the help of hardware technology localization and equipment production standardization, so as to realize the economy of virtual reality technology in police application; Secondly, we should focus on the customized design of training content, and closely cooperate with police departments to develop relevant training content modules to maximize the practicability of the system. Finally, through systematic training and publicity, the police should constantly improve their adaptability and proficiency in virtual reality technology, and improve the mechanism construction through the evaluation of virtual reality training to maximize the training effect. Through the collection and improvement of multi-faceted quality and technology, the potential of virtual reality technology in police physical training can be tapped, and effectively give the modernization and efficiency of police work to guarantee.

6 Conclusions

Virtual reality technology provides a new method and idea for police physical training, and its immersion, interaction and safety significantly improve the training effect. In the future development, it is necessary to further solve problems such as technical cost and content design, and explore more diversified application scenarios. Through continuous optimization, virtual reality technology will become an important part of police physical training and provide an important guarantee for improving the overall quality of the police force.

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