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Application of "Virtual Reality + Haptic Feedback" in Education: Opportunities and Challenges

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Abstract: *The development of virtual reality (VR) has brought new learning experiences to learners, helping them to acquire a variety of knowledge and skills. However, current VR technology is mainly focused on audio-visual stimulation, and the learner's experience is often less natural. The introduction of haptic feedback (Haptics) is expected to significantly improve this limitation and provide a more natural experience for learners. Some researchers have explored the "virtual reality + haptic feedback" (VR+Haptics) teaching model and found that it has a positive impact on learning outcomes. The purpose of this paper is to analyze the educational application cases of VR+Haptics and discuss the opportunities and challenges it may face, in order to provide useful reference and enlightenment for the application of VR+Haptics.*

Keywords: *Virtual Reality; Haptic Feedback; Educate; Opportunity; Challenge*

1. Introduction

In the "Guiding Opinions on Promoting the Construction of New Educational Infrastructure and Building a High-quality Education Support System", the Ministry of Education and other six departments proposed to build smart teaching facilities and popular teaching applications: relying on perceptual interaction, simulation experiments and other equipment to create vivid and intuitive new classrooms, as well as hybrid, cooperative, experiential, and inquiry-based teaching under the condition of popularizing new technologies, and exploring new teaching methods[1]. In recent years, virtual reality (VR) technology has gradually penetrated the field of education, bringing revolutionary changes to the field. With the help of VR technology, we can optimize the practical teaching environment on the computer, effectively overcome the limitations of the practice site, and reduce the wear and tear of equipment. Learners are no longer limited by time and space, and they can enter the learning environment anytime and anywhere to learn; It can also enable contextualized teaching, allowing learners to actively construct knowledge in virtual learning situations[2]. When VR technology is applied to regular classroom teaching, it often does not reach the level of immersive virtual reality because it mainly focuses on audio-visual stimuli and pays relatively little attention to touch. This limitation may lead to a certain lack of deep experience of the learning object by the learner.

Haptics refers to a discovery mode that uses tactile sensory channels to perceive the characteristics of objects (e.g., hardness, texture, shape, temperature, etc.) through actual and active tactile actions[3]. Haptic feedback, which is sometimes extended to force feedback, provides a two-way flow of information and effectively extends the perceptual limits of VR in teaching, allowing learners to be more immersed in the virtual environment and reinforcing knowledge. Through the learning environment composed of VR+Haptics, it can expand the form and scope of learners' perception of learning content, and improve learners' cognitive level of learning content. This combination can not only promote the extension of learners' cognitive context, but also help learners build a virtual cognitive world and provide multi-sensory cognitive resources to enrich the cognitive interaction environment[4]. Therefore, the combination of VR and Haptics has increasingly become an important field for educational researchers and practitioners to explore. This paper analyzes the application cases of VR+Haptics in the field of education, and discusses its possible opportunities and challenges, in order to provide useful reference and enlightenment for the application of "virtual reality + haptic feedback".

2. Application of "Virtual Reality + Haptic Feedback" in the field of education

In recent years, scholars at home and abroad have carried out a series of VR+Haptics teaching

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activities, and this section discusses several VR+Haptics teaching cases in different disciplines, in order to reveal the potential and advantages of this teaching model.

2.1 Physics Education

The concepts of electricity and magnetism are the foundations of physics, and they explain the behavior of charged particles in an electric and magnetic field, as well as the interaction between them. Due to the abstract, complex and invisible nature of electromagnetic concepts, it is difficult for teachers to teach in a clear and easy-to-understand manner, and they usually annotate them, quickly explain the basics, and use most of the lessons on rote memorization, so it may lead to difficulties in understanding for some students.

Magana et al.[5] solved this problem by creating a visual-tactile simulated learning environment that improved students' understanding of the concepts of electricity and magnetism. In the environment of visual tactile simulation, the visual simulation of the magnetic field consists of two 3D bar magnets, the red part of the magnet represents the North Pole, and the blue part of the magnet represents the South Pole, which is rendered into 3D virtual space, and the colored arrows around the magnet represent the field vectors. The visual simulation of the charged particles is presented by a 2D simulation of two static charges. With the spherical grip of the haptic device (Novint Falcon), students can feel changes in force at different positions in a magnetic or electric field. Using the VR+Haptics teaching mode, students can intuitively observe and get in touch with the physical phenomena of "electricity" and "magnetism". This learning experience helps students gain a deeper understanding of electromagnetic concepts that would otherwise not be directly experienced. The results show that the learning effect of students in the visual and tactile simulation environment has significant advantages over traditional teaching methods.

2.2 Geography education

Some geographical phenomena cannot be directly perceived by humans due to their large spatial and temporal spans, such as ocean acidification, volcanic activity, and mountain formation. The damage of ocean acidification to marine ecosystems is an urgent problem to be solved, but the damage caused by ocean acidification to marine organisms is a chronic process, which is not directly and immediately observable. In addition, the long distance between human behavior and environmental damage can easily lead to ignoring the severity of the problem, resulting in a lack of public awareness of environmental problems[6]. The public is more likely to link the effects of environmental damage to their own behaviour and engage in activities to protect the environment if they have experienced it firsthand. But recommending one's experience of environmental damage in nature to promote environmentally friendly behaviour would have prohibitive personal and societal costs and could be dangerous (the cost would be too great for people to experience a flood firsthand to understand the consequences of global warming).

VR+Haptics is able to simulate these experiences that are difficult or impossible to experience in the real world and produce similar results in a cost-effective and safer way. Ahn et al.[7] used VR+Haptics technology to design a marine ecology scenario that allows learners to experience the devastating changes in the ocean over the decades in just a few minutes. Under these conditions, learners become corals and enter a virtual ocean to experience the negative consequences of ocean acidification. In this virtual environment, learners are able to see a scaled, three-dimensional coral double and can look around the virtual world as if they were walking into the body of a coral double. Suddenly, the nets appear in front of the coral stand-in and begin to hit the coral double repeatedly. At the same time, the researchers moved the subject's torso inside the room to induce body transfer. Learners can observe the erosion of the coral body and the fracture of its limbs, accompanied by the breaking of the coral branches, and the haptic feedback in the form of floor vibrations combined with the sound of cracking, and be able to feel the destruction of the coral's habitat and the pain of its own body. Through VR+Haptics technology, learners can become corals and gain a rich sensory experience (sight, sound, touch) that can lead to a stronger sense of immersion, and this virtual experience can help learners better understand the negative consequences of ocean acidification on marine life, and then better understand the meaning of protecting the environment and put it into action.

2.3 Medical education

One of the main problems faced by medical education in China is that medical laboratory teaching resources are expensive and cannot be repeated. However, due to its advantages of low cost, safety, reliability and reproducibility, virtual surgical operation training has become a new breakthrough with

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great potential for development in solving the dilemma of medical education.

Shenyang et al.[8] conducted an experimental study on whether colectomy surgery can promote surgical skill acquisition after adding force feedback interaction in a VR environment. The experiment was based on the Virtual Surgical Support Platform (UniVRLap) and the force feedback device 3D System Touch, and was carried out on 43 fifth-year medical clinical students from Beijing Aerospace General Hospital. Learners can control the surgical instruments in the virtual environment by operating the force feedback device handle, and can feel the force and touch from the virtual tissues and organs on the operation of the surgical instruments in real time. In this experiment, an experimental group and a control group were designed, and the experimental group gave force feedback while the control group did not. After the experiment, the scores were carried out according to the four dimensions of the GOALS evaluation framework (depth perception, bimanual coordination, surgical efficiency, and tissue processing), and then the experimental data were statistically analyzed, and the experimental results showed that interactive learning with increased force feedback could not only make the learning situation more realistic and immersive, but also play a positive role in the process of surgical skill acquisition.

Based on the above case analysis, we can deeply understand the teaching potential of VR+Haptics teaching mode, if Haptics and VR can be effectively integrated, it will help to improve the learning effect of learners, enhance their concentration in the learning process, and bring them a deep flow experience of physical and mental unity. Therefore, we should actively explore and apply VR+Haptics to bring innovative breakthroughs to the field of education.

3. Opportunities and challenges faced by "virtual reality + haptic feedback".

Researchers have discussed the effectiveness of VR+Haptics in teaching, and some progress has been made. Their research revealed an important finding that VR+Haptics significantly improved learners' learning efficiency compared to traditional VR environments. It is more suitable for skills training, inexperienced learners, and instructional design for extended testing[9]. This discovery has been widely valued by education practitioners, and they have begun to pay attention to VR+Haptics in order to apply it in teaching practice. This trend brings new opportunities for teaching and learning:

1) Improve learning outcomes

We learn and understand the world through our five senses – sight, hearing, touch, taste, and smell. According to the proportion of information received, vision dominates at 83%, followed by hearing at 11%, while touch, taste and smell account for 1.5%, 1% and 3.5%, respectively. It can be seen that hearing and vision are the key channels through which we obtain information[10]. Despite their large capacity for audiovisual information, they tend to be easily forgotten. For example, we may encounter a situation where we hear a familiar song, but we can't remember its name or singer. Or seeing a familiar host on TV and not being able to remember his name. In contrast, the memory generated by the sense of touch is much deeper and more persistent[11], and it can be used as an effective memory aid to help us consolidate and retain what we have learned.

The VR+Haptics teaching mode not only enables learners to quickly obtain a large amount of information through the audio-visual channel, but also helps them to memorize the knowledge more firmly through the tactile channel. In addition, the additional tactile channels provided by VR+Haptics can reduce the cognitive load in the learning process and allow learners to have a deeper understanding of complex concepts[12]. Multi-channel learning has significant advantages over single-channel learning. Single-channel learning may only provide a partial understanding, while multi-channel learning can enhance learners' understanding and awareness of knowledge. By blending multiple sensory experiences, learners can grasp the learning content more comprehensively and deeply, resulting in better learning outcomes.

2) Enhance concentration

At present, regular classroom teaching mostly relies on audio-visual interaction, that is, the teacher mainly explains, and the students are mainly responsible for listening. However, a single audio-visual interaction for a long time is often difficult to sustain the learner's attention, and even the slightest movement may become a source of interference, resulting in the learner's attention being distracted, making it difficult to concentrate and concentrate on learning. In contrast, VR+Haptics revolutionizes classroom teaching by providing tactile interactive experiences that are often more difficult to divert than audiovisual stimuli[13]) and greatly enhance learners' ability to concentrate.

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3) Enhance the learning flow experience

Currently, most virtual classrooms only reach the level of non-immersive or semi-immersive experiences and do not yet provide high-quality immersive learning experiences. The main reason is that learners lack the awareness of actively constructing knowledge in the learning process, and in most cases, they are in a state of passive reception of knowledge. There are two basic conditions for the flow experience to be realized: first, the activity needs to have timely feedback, and second, the learner needs to have a sense of ownership of the activity[14]. Through Haptics technology, a bridge of information interaction can be built between the learner and the VR learning environment, which helps the learner to actively control the learning intention. Therefore, the use of VR+Haptics can greatly promote the flow experience of learners and make them more engaged in the learning process.

Of course, there are certain challenges to the widespread use of "VR+Haptics" in education:

1) Technology maturity and cost

Due to the long-term dominance of visual centrism in media research, tactile media research has been neglected[15], which has led to the development of haptic technology not very mature. First of all, the accuracy, realism and responsiveness of Haptics technology need to be further improved. In addition, how to perfectly blend Haptics and VR content to create a highly realistic experience is an urgent problem to be solved. Secondly, the higher cost of haptic feedback devices (e.g., Phantom Premium, Phantom Omni, Novint Falcon, haptic gloves, etc.) limits their popularity in school settings. Achieving the maturity and stability required for VR+Haptics for educational applications and controlling costs to fit education budgets remains a challenge.

2) Teacher training and educational resource design

As the gatekeeper of new technologies entering the classroom, teachers' recognition and support of new technologies is the key to whether new technologies can be applied to the classroom. In order to flexibly apply new technologies in the classroom, it is necessary to provide teachers with special training to familiarize them with the characteristics of new technologies and how to use them. How to effectively combine VR+Haptics technology with traditional teaching methods is also an urgent problem to be solved. In addition, designing relevant educational resources and content is also a major challenge. Due to the fact that VR+Haptics technology is still in the development stage, coupled with the low reusability of educational resources and the high upfront investment cost, the available educational resources are relatively limited[16]. In order to improve the utilization rate of VR+Haptics educational resources and reduce input costs, how to fully tap and utilize limited educational resources and maximize their value has become an urgent problem to be solved.

3) Evaluation of learning effect

The teaching mode of VR+Haptics fully mobilizes the multiple sensory channels of learners, greatly enhances the immersion of learning, and is conducive to stimulating learners' interest and motivation for active learning. However, due to the diversity and complexity of the education field, the current learning effect evaluation methods for VR+Haptics are not perfect enough, and there are still some shortcomings[17], which need to be further improved and optimized.

4. Conclusion

The teaching model of VR+Haptics has great potential for development in the field of education. It not only helps to improve the learning effect of learners, but also enhances their concentration and improves the learning flow experience. However, this innovative model also faces challenges in terms of technology maturity and cost, teacher training and educational resource design, and learning effect evaluation. In order to overcome these challenges, the education sector needs to continue to explore and innovate. Only through unremitting efforts and innovation can we give full play to the advantages of VR+Haptics and promote the continuous progress and development of the education field.

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