

Research Article

Investigating the Effect of VR + Haptics Approach on Students' Flow Experience and Outcomes: An Empirical Study on VR Laparoscopy

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Background. Virtual reality-based surgery training has become a promising trend in the sector of clinical education. Prior studies have confirmed the effectiveness of VR-based surgical simulators on training surgeons. Most existing papers employing subjective methods explored the students' overall perceptions of surgical skills. However, few studies, from the multidimension perspective of learning performance, investigate how VR improves surgery skills. **Participants.** 37 college students were recruited in comparative experimental research. The experimental group was equipped with a VR + haptic surgical simulator, while the VR simulator without haptic feedback was used for the control group. **Method.** The study resorted to physiological approaches to investigate the influence of the VR laparoscopic surgical training system on students' performance. **Results.** The experimental group scored higher than the control group in flow experience and has better performance in the four dimensions of operation evaluation skills. **Conclusion.** The study deposited that learners are more likely to exert to flow experience in a learning situation with haptic feedback, which will further improve medical students' performance.

1. Introduction

Virtual reality technology has revolutionized traditional education, and it has involved medicine, architecture, and other disciplines. Virtual reality, featuring immersion, interactivity, and imagination, is deeply integrated with medical research. The effect of VR on clinical skills training is increasingly becoming prominent [1]. The traditional training methods of laparoscopic surgery mainly focus on video learning and animal tests. However, learning from the traditional sources leads to less interaction between organs and tissues, and students' lack of eye-hand coordination is barely inspired. Besides, the anatomy of animals is also different from that of human beings. Alternatively, VR surgical simulators can overcome the above shortcomings, providing a repeatable and controllable environment to acquire basic surgical skills [2].

However, the traditional VR technique only provides a watching model, and the deep interaction in human-computer interaction warrants further study. The combination of VR haptic feedback would bring about an innovative approach to promote students' learning outcomes and perceptions and practically improve the attractiveness and authenticity in surgical training [3]. Employing the VR + haptics approach helps learners continuously undergo the procedure, reducing the cost of physical animal tests [4], because the simulation process by VR can effectively transfer users to immersive situations [5, 6], which trigger the generation of users' flow experience [7].

This study was designed based on the laparoscopic surgery training system in the UniVRLap platform [8] to carry out learning and training of colectomy surgery. The participants were randomly grouped into VR + haptic feedback group and

VR group. First, the trainees perform the pretest of box colectomy surgery skills. Then, they perform the strong feedback interactive VR training and the weak feedback interactive VR training. Finally, they perform the box colectomy operation test. From the perspective of flow experience, the impact of the haptic feedback on medical students is quantitatively measured, and wearable devices are used to obtain student heart rate data during training. In this research, we propose three research questions:

- (1) Can VR+haptic feedback training improve the surgical skills for medical students?
- (2) In what ways can VR+haptic feedback training improve the skill acquisition for medical students?
- (3) Does the VR+haptic approach have a positive influence on learners' substantial flow experience?

2. Literature Review

2.1. VR Laparoscopy. Minimally invasive surgery has been proved to be a reliable approach to reduce surgical trauma, accelerate postoperative recovery, and shorten hospital stay. Winfield et al. [9] first conducted laparoscopic partial nephrectomy, which opened a new era of minimally invasive partial nephrectomy. Subsequently, an increasing number of operations were completed under laparoscope. The use of virtual reality (VR) training becomes a necessary prerequisite for junior doctors to participate in actual operations. Ideal virtual reality devices can be used for fundamental skills training in laparoscopic surgery and can fully simulate the entire surgical procedure. The emergence of virtual reality (VR) laparoscopic simulation technology has increased the attractiveness and authenticity of surgical training [3]. Moreover, haptic feedback is a crucial technique in the interactive VR system. The function is to realize human-computer interaction in the virtual roaming 3D space and expand human perception. Constructive learning theory suggests that "learning is a real situation of experience" [10]. The learning environment constructed by virtual reality is mostly applied to the training of specific operating skills, as well as the rare, dangerous, and costly construction scenarios in life.

2.2. Flow Experience. Flow experience is an experience of being completely immersed in the activity, which refers to a person who devotes himself to a particular activity and achieves a delightful mental state [11]. The concept, firstly proposed by Csikszentmihalyi in the 1960s, found that when people maximize their physical and mental states, they often produce an ultimate optimal experience [11]. Some experimental studies compared the level of personal experience streaming and immersion when viewing media content in VR and ordinary displays, and results indicated that users in VR context experience better perception of streaming and immersion [12]. In return, immersive experience helps users to improve their creative work [13].

2.3. The Composition of Flow and Classic Scale. Csikszentmihalyi proposed to divide the flow experience into 9 elements: clear goals, timely feedback, the balance of

challenges and skills, integration of behavior and consciousness, elimination of interference in consciousness, free control, the disappearance of self-consciousness, abnormal sense of time, and self-purposeful experience [14]. Flow, characterized by the complete absorption in what one does, is a highly rewarding state of consciousness [15]. Achieving this state can help people feel greater enjoyment, energy, and involvement that they may feel time past so soon. Some researchers have also proposed some other dimensions to measure flow experience, including curiosity [16, 17], exploratory behavior, playability [18], higher state of ability [19], and stress and tension [20].

Flow theory has been widely used in information systems, human-computer interaction, education, and other fields [21]. In terms of human-computer interaction, Hoffman and Novak proposed a flow model in a computer-aided environment [22]. Their flow patterns include "positive emotions," "exploratory behavior," and "challenge/wake," which can be considered a happy element. Trevino and Webster had used flow theory to measure users' gameplay in HCIs and proposed four dimensions to measure flow from control, concentration, curiosity, and intrinsic interest [23]. Koufaris applied flow theory to online consumer behavior and measured four flow structures including concentration, challenge, skill, and perceptual control [24].

In the context of VR, the flow experience is considered as the embodiment of the affective presence and immersion of these technologies. There are a large number of studies on the generation and structure of virtual reality central flow experience. Nah et al. used flow, presence, positive emotion, and brand equity theories to test the effects of using 2D and 3D virtual environments on presence, enjoyment, brand equity, and behavioral intentions [25]. Sweetser and Wyeth believed that the central flow of electronic games (game flow) consists of control, feedback, immersion, attention, challenge, player skills, clear goals, and social interaction [26]. Smith-Stoner and Willer deposited that streaming is a psychological state that contributes to the entertainment of gamification, in which individuals deserved pleasure from the experience of streaming, and the occurrence of streaming can be stimulated by using interactive media [27].

To sum up, the current study summarizes the existing research on flow experience and proposes a flow experience scale for medical training in a virtual reality environment.

2.4. Flow Reflected in Physiological Data: Heart Rate Measurement Methods. Flow as an objective flow indicator can be conceptualized in both physical and physiological dimensions. Studies have shown that the challenging and demanding nature of flow activity may cause physiological changes, similar to those observed when individuals are overloaded with task demands [28]. Heart rate variability (HRV), measuring the changes in the rate of heartbeat, reflects the activity of the two branches of the autonomic nervous system (ANS). Peifer et al. [29] confirmed a strong relationship between low-frequency variability (HRV) and flow experience, that is, HRV has a positive linear relationship with flow experience. Participants with higher HRV

experienced higher levels of flow. Previous studies have also found that the increase in HRV is related to the activation of sympathetic nerves [30] and is usually accompanied by low heart rate variability [31]. Harmat et al. also found that higher flow is associated with lower low-frequency HRV [32]. Tian's research shows that flow experience is related to faster breathing, deeper breathing, moderate heart rate, and moderate heart rate variability [33]. Therefore, heart rate is considered as an effective measurement to explore flow experience.

In simulated laparoscopic surgery, the flow experience is regarded as incredible factor driving effective surgery. Studies have shown that the fulfillment of flow experience during laparoscopic surgery could improve the effectiveness of the operation, thereby enhancing patient safety [34]. However, there are very little research studies on the flow experience in VR simulated surgery. This study, therefore, employed physiological methods to verify the importance of interaction in VR surgical training. It reveals the relationship between the learner's flow experience in VR laparoscopic surgery training and performance and puts forward suggestions for future VR medical education design.

3. Materials and Method

3.1. Participants. Thirty seven fifth-grade medical majors were recruited from Beijing Aerospace General Hospital in this study, and none of them had operated a VR surgical simulator before. The participants were randomly grouped into two groups: 17 participants in the control group (without haptic feedback) and 20 participants in the experimental group (with haptic feedback). The demographics of the participants are shown in Table 1.

Both groups were assigned to VR surgical settings, in which the auditory tissue deformation, electrocautery, and blood flow during the procedure were visualized. The participants in the experimental group conducted the virtual surgery with haptic sensors in real time, and they were able to manipulate surgical instruments through the haptic device. To ensure the homogenization of both groups, the skill level and surgical experience were tested, and no significant difference was found between the experimental and control groups.

3.2. Instruments

3.2.1. VR Intelligent Medical Training System. The laparoscopy simulator (UniVRLap) employed in this research was developed by the State Key Laboratory of Virtual Reality Technology and Systems, Beihang University. The computation module is a high-performance PC connected with a touchscreen monitor (1920_1080 dpi). The hardware parameters are as follows: Intel(R) Core(TM) i5-8500 CPU @3.00 GHz with 6 cores and NVIDIA GeForce GTX 1060 with 6 GB memory. The software is run on Windows 10 64 bits professional version. The haptic devices employed in the experiment are produced by American 3D System Company, and the devices can control the surgical instruments

with 6 degrees of freedoms (DOFs) [35]. The force feedback workspace is approximately 6.4 * 4.8 * 2.8 inches.

The simulator can simulate the deformation of the colon, the separation of colon tissue, and interactions between organs and surgical instruments during colectomy. Based on position-based dynamics, the simulation is a general simulation approach featuring high speed and robustness that could model rigid bodies (surgical instruments), soft tissue, fluids (bleeding effects), etc [36]. As shown in Figure 1, participants used the right hand to manipulate the grasper to drag the colon tissue, and the left hand operated the L-hook to electrocute the membrane tissue on the colon surface, while two-foot pedals were utilized to activate the electrosurgical coagulation during surgery training. During training, the two groups of participants were asked to perform as smooth and rapid electrocautery around the colon as possible.

The pre-post examination was conducted in a reformed plastic box (15 * 7 * 5 cm) placed into a commercial laparoscopic physical training box (38 * 27 * 27 cm) produced by Beijing Yikang Vino Technology Co., Ltd. As illustrated in Figure 2, the participants were assigned to operate the laparoscopic surgery instruments inserted into the training box through the holes. The left-hand surgical instrument is a grasper, and the right hand is a scissor. A high-resolution camera connected with a laptop is placed into the training box, and the participants were able to monitor the training procedure inside. After placing a segment of the intestine into the plastic box, the participants could start to cut the intestine, and the whole process was recorded and saved on the laptop.

3.2.2. Flow Experience Scale. Flow is defined as a psychological experience reflecting cognitive regulation in behaviors [37, 38], which is adaptive to the current research. This study developed a five-point Likert scale to measure the flow experience of VR medical training based on Cheng's scale [39, 40], which contains five dimensions, namely, heutagogy, grit, interaction, goal clarity, concentration. A total of 26 items shown in Appendix A are used to measure whether learners had flow during previous VR medical training. This research is divided into three stages: the evaluation of the validity of the scale items was conducted in the first stage; the pretest, reliability test, and validity test were performed in the second stage; and in the final stage, the scale was released to measure the flow experience of senior medical students in virtual surgery.

After evaluating the validity of the content, the modified version for pretesting, reliability testing, and validity testing was proved. Cronbach's alpha (Cronbach's coefficient method) is a method of examining reliability. It was proposed by Lee Cronbach in 1951. It is the most commonly used reliability analysis method in social science research. In general exploratory studies, the baseline of Cronbach's alpha coefficient is 0.6 and the value above 0.8 is considered to be highly reliable. Cronbach's alpha coefficient reaches 0.804, while the KMO and Bartlett

TABLE 1: Demographics of participants.

Variables	Control group	Experimental group
Num. of participants	17	20
Mean value of ages	21.90	21.95
Gender	49%	51%
Male	9	7
Female	7	13
Gaming frequency (1–5 Likert scale)	2.12	1.4
Num. of left-handed participants	0	1
Experience in surgical skills training	76.4%	55%
Other experience with any VR training	0%	0%



FIGURE 1: VR laparoscope colectomy simulator.



FIGURE 2: Pre-post dissection task on colectomy.

coefficients are 0.729, and sig = 0.000. The reliability of the scale is satisfactory, which ensures the solidness and fitness of instruments.

3.2.3. Physiological Measurement Instruments. Although survey is generally employed in exploring individuals' flow experience [41], it may interrupt the immersive experience in virtual reality. Given the concern about this limitation, electrophysiological measurements such as the electrocardiogram (specifically heart rate) were suggested to be an alternation. These psychophysiological approaches can effectively promote learners' immersive experience; additionally, the data collected from psychophysiological measurements are objective data avoiding the subjectiveness.

In this research, a Polar heart rate chest strap was utilized to measure heart rate during medical training. As shown in Figure 3, the Polar S810i heart rate monitor was used in this study, and it has been approved as a reliable instrument in research fields [42, 43], especially in the medical test [44].

3.3. Procedure. The procedure of this study, as shown in Figure 4, consists of three steps. In the first step, the experimental goal and procedure were introduced to participants, which was followed by the random division of participants into two groups, and they were required to conduct the presurvey. Each participant had about 20 minutes to accomplish the preexamination: a dissection task in human colectomy.



FIGURE 3: Heart rate acquisition instrument.

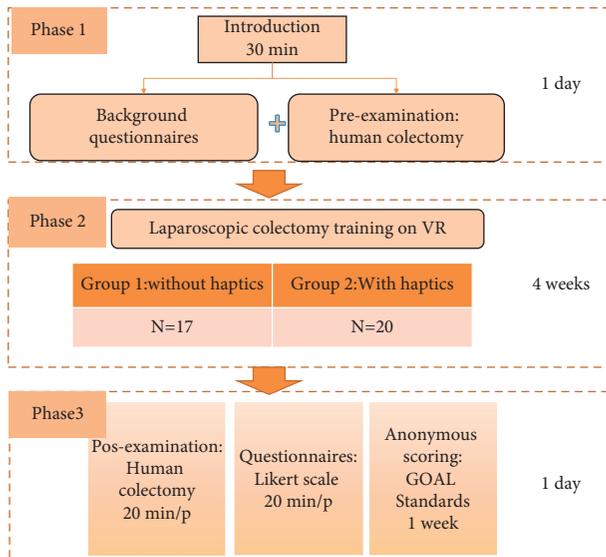


FIGURE 4: Flowchart of the experiments.

In the second step, two groups were trained using the developed VR laparoscopic colectomy simulator for four weeks, with 1.5 hours per day on average for each participant. Group 1 was the control group without haptic feedback, and group 2 was the experimental group with haptic feedback enabled.

In the third step, all participants were requested to reoperate the dissection task in human colectomy as the posttest, which was followed by the postsurvey. To explain the results of the survey, we interviewed 16 participants and recorded the audio dialogues. Finally, all the pre-post examination videos were collected and sent to four senior laparoscopic surgeons. After watching the test videos, the four experts scored the learners' performance independently and anonymously based on the Global Operative Assessment of Laparoscopic Skills (GOALS) standard [1], which assesses four dimensions of laparoscope surgery skills. The mean values of the scores are used in the following analysis.

4. Results

In this experiment, two main research questions would be investigated. The first is the impact of VR haptic feedback on the flow experience for medical students. The second is the impact of VR haptic feedback on their skill performance.

4.1. Flow Experience Data Analysis. To investigate the impact of VR-based medical haptic feedback training on learners, the *t*-test was employed to explore whether there is a statistical difference between the VR + haptics group and the VR group. As shown in Table 2 and Figure 5, the average total flow experience scores of the experimental group and the control group are 3.8975 (SD = 0.27175) and 3.1285 (SD = 0.36032) respectively, which indicate that there is a significant difference between the two groups ($t = 7.392$; $p < 0.001$) in terms of the haptic feedback interaction on the flow experience.

We consider flow experience including five dimensions: heuristics, goal clarity, interaction, concentration, and grit. The current research further investigated the impact of different dimensions of the flow experience among learners. As shown in Table 2, the experimental group has significant differences in all dimensions compared with the control group.

- (i) In terms of skill challenge, the experimental group has the most considerable difference from the control group ($t = 7.639$, $p < 0.01$). Since personal skill level is one of the most important antecedents of mobility, the haptic interactions can enhance learners' ability to challenge and skills [45].
- (ii) In terms of grit, there is a significant difference between the experimental group and the control group ($t = 3.028$, $p < 0.01$). Previous studies have shown that traditional educational games have poor learning effects, while VR games can increase humans participation and enthusiasm for learning [46]. The results of this research prove that the flow experience obtained by the VR haptic feedback training can improve learners' grit for participation.
- (iii) In terms of clear goals, the difference between the experimental and control groups is the smallest ($t = 2.694$, $p < 0.01$). The two groups of students received clear goals at the beginning of the experiment, and they continued to receive different stage goals. Therefore, VR haptic feedback training has little effect on the clear goals in the flow experience.
- (iv) In terms of concentration, the score of the experimental group was significantly higher than that of the control group ($t = 3.228$, $p < 0.01$). Therefore, it is shown that the immersion brought by VR haptic feedback training can enable medical students to have a stronger concentration in skill training.
- (v) In terms of interaction, there are also significant differences between the experimental group and the control group ($t = 3.114$, $p < 0.05$). The experimental group feels more interaction than the control group. This interaction can give learners a sense of enjoyment and experience of exploration [23]. Therefore, we can conclude that improving interactivity is essential to maintain the learner's concentration in virtual surgery. It also helps to improve the learner's sense of control and immersion.

4.2. Skills Performance Data Analysis. The pre-post test on colectomy was evaluated from four dimensions according to

TABLE 2: Descriptive statistics of the control group and experimental group scores on flow experience.

	Group	<i>n</i>	Mean	SD	<i>t</i>
<i>Heutagogy</i>	Experimental group	20	4.49	0.47	7.64
	Control group	17	2.95	0.74	
<i>Goal clarity</i>	Experimental group	20	4.15	0.67	2.6
	Control group	17	3.47	0.87	
<i>Interaction</i>	Experimental group	20	3.27	0.58	3.11
	Control group	17	2.66	0.62	
<i>Concentration</i>	Experimental group	20	3.83	0.47	3.22
	Control group	17	3.35	0.43	
<i>Grit</i>	Experimental group	20	3.74	0.49	3.03
	Control group	17	3.21	0.58	
<i>Flow experience</i>	Experimental group	20	3.89	0.27	7.39
	Control group	17	3.12	0.36	

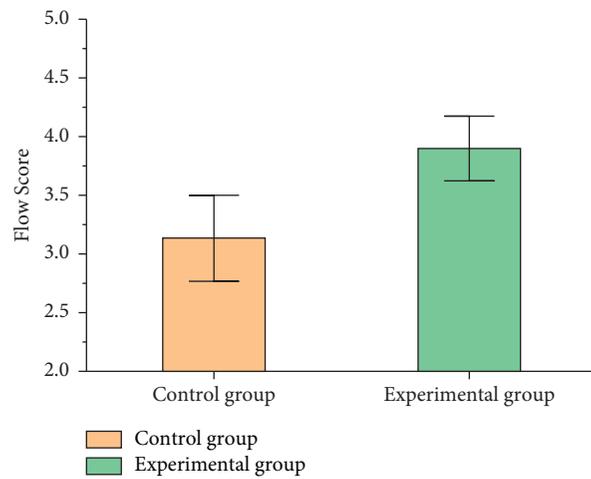


FIGURE 5: Flow experience score.

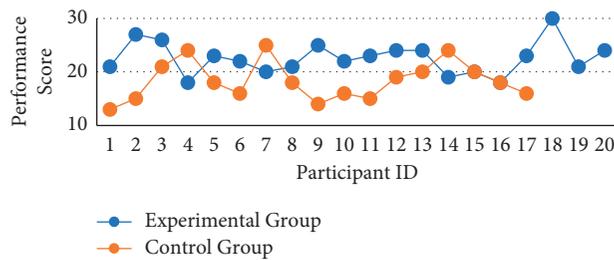


FIGURE 6: Performance score comparison between the control group and experimental group.

TABLE 3: Descriptive statistics of the control group and experimental group scores on performance.

	Group	<i>n</i>	Mean	SD	<i>t</i>
<i>Depth perception</i>	Experimental group	20	6.60	0.94	5.49
	Control group	17	4.71	1.16	
<i>Bimanual dexterity</i>	Experimental group	20	7.10	1.07	5.69
	Control group	17	5.00	1.17	
<i>Efficiency</i>	Experimental group	20	7.15	0.99	6.57
	Control group	17	4.89	1.11	
<i>Tissue handling</i>	Experimental group	20	6.70	1.38	4.65
	Control group	17	4.59	1.37	

the GOALS standard. As shown in Figure 6 and Table 3, the score of surgery skill tasks in the control group is significantly lower than that of the experimental group. The results indicated that training with VR+haptics-based laparoscopic simulators will improve the overall performance for medical students.

- (i) In terms of depth perception, the performance of the experimental group was significantly higher than that of the control group ($t = 5.487$, $p < 0.05$). The results indicated that tactile feedback in virtual reality training could improve depth perception skills.

However, due to the different experimental materials, there are some differences in the efficiency of the two groups ($t = 5.691$, $p < 0.01$). Because the haptic device can promote learners high immersive sense in the virtual context, we found that the experimental group can complete colon surgery more quickly and efficiently after a week of training.

From the aspect of bimanual dexterity, the experimental group participants obtained relatively higher scores than their counterparts in the control group ($t = 5.691$, $p < 0.01$). During the training and real laparoscope surgery, the motion of the hands is opposite to the motion of surgical instruments. It is a challenge for novice participants to operate surgical instruments in such a short time skillfully. Thus, there is no significant difference between these two groups. To improve the proficiency of operating laparoscopic instruments, participants must take more time to practice and adapt to the environment.

In terms of tissue handling, the score of the experimental group was significantly higher than that of the control group ($t = 4.651$, $p < 0.01$). This shows that in real laparoscopic surgery, tactile training is more helpful in improving tissue handling.

According to the standard deviation results of the two groups, the standard deviation of the experimental group was smaller than that of the control group in multiple dimensions. The results showed that after a period of training, the students not only performed better in the operation but also had stronger stability, and the differences between the experimental groups were smaller.

4.3. Analysis of Participants' Heart Rate. From Table 4, we can clearly see the comparison of the heart rate between the control group and the experimental group. It can be seen that the average heart rate and maximum heart rate of the experimental group are significantly lower than those of the control group ($p < 0.05$), while the minimum heart rate is not much different.

By separately calculating the internal variances between the two groups, it can be found that the average variance of the heart rate of the experimental group is smaller ($SD = 4.16$), and the heart rate changes more smoothly, while the average variance of the control group is larger ($SD = 4.81$) and the heart rate fluctuations are more prominent (Figure 7). The variance of the two groups is quite different ($t = 1.186$, $p = 0.071 < 0.1$), which may indicate that effective interaction can bring a more stable heart rate.

TABLE 4: Descriptive statistics of the control group and experimental group on heart rate.

	Experimental group (VR + haptics) ($N = 20$)		Control group (without haptics) ($N = 17$)	
	Mean	SD	Mean	SD
AVG HR	92.9603	11.65552	96.5088	11.47144
Min HR	85.2439	10.51613	85.4878	10.38538
Max HR	101.6829	12.56073	107.2927	12.05455

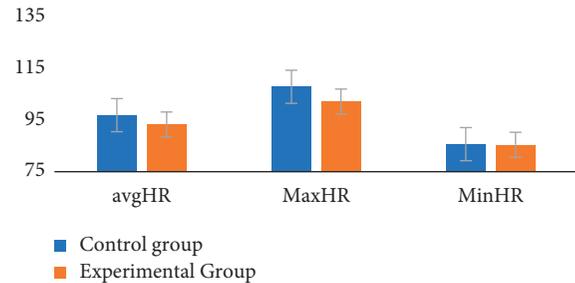


FIGURE 7: Heart rate comparison.

5. Discussion

5.1. The Impact of VR Interaction on the Effect of Medical Training. The current research predicts that the laparoscopic surgery training system, based on VR+haptics technology, is profound in clinical teaching. Haptic feedback is considered to be one of the most critical and challenging components in virtual reality simulators. To examine the performance before and after colectomy training on the virtual laparoscopic simulator, the participants were randomly divided into two groups according to whether they were equipped with haptic feedback. The experimental results show that the VR+haptics technique significantly improved students' operational skills and generated a stronger flow experience during the learning process.

5.2. The Impact of VR Interaction on Skill Acquisition. This study used the GOALS standard to evaluate the learning performance in the acquisition of laparoscopic colectomy skills. The GOALS standard is regarded as an effective instrument with a set of internationally accepted surgical skill evaluation methods with structural validity. Kim et al. [47] provided empirical support for the relationship between interactivity and flow challenges and skill dimensions [48]. In terms of skill improvement, we found that haptic devices can significantly enhance students' depth perception ability. Students in the experimental group expressed their understanding of the entire process, while the control group paid more attention to details, such as device manipulation. The students in the control group may have felt freer to explore the instruments and surgical methods, which indicated that students can benefit from independent learning methods.

However, there is little difference between the two groups in terms of hand coordination. This may be due to the short training time, and the learners have not yet mastered the skills of surgical instruments in a short time.

5.3. The Role of VR + Haptics on Four Dimensions of the Flow Experience Model. There is little research on interactive learning environments focusing on haptic feedback in medical education. Through two sets of experiments, the students in the experimental group scored higher in flow experience, which shows that the immersive learning environment constructed by the virtual reality training box can bring learners a better sense of immersion. The dual-channel sense of vision and haptics strengthens users' emotional needs and further achieves the best experience state of learning.

6. Conclusion and Limitations

In this study, we employ a laparoscopic surgery simulator in a VR environment to promote students' skill acquisition. To explore whether the laparoscopic surgery training system with haptic feedback can significantly impact learners, an experiment was designed to evaluate learners' performance and flow experience. The experimental results show that the skills of the experimental group with haptic feedback have been substantially improved. The scoring of flow experience in experimental group was higher than that of the control group. Besides, the changes in heart rate are more stable, which supports that there is a better immersive experience for the experimental group.

However, the sample pool in this study is relatively small. It is exploratory to investigate the impact of VR + haptics on learning performance with the large-scale sample in the future. Besides, with the development of multimodal analysis techniques, other physiological data generated in the VR environment, such as EEG and eye-tracker data, were suggested to be involved. Currently, this study only explores the interstitial relationship between heart rate and flow experience. In the future, more biofeedback approaches are needed to be used to analyze the relationship between physiological data and flow experience.

Appendix

A. The Scale of Flow Experience in VR + Haptics Context

- (1) When I conduct the experiment, there is very little waiting time between my actions and the computer's response.
- (2) Interacting with the experiment is fast.
- (3) The experiment I performed usually loads quickly.
- (4) Playing the experiment challenges me.
- (5) Playing the experiment challenges me to perform to the best of my ability.

- (6) Playing the experiment provides a good test of my skills.
- (7) I am extremely skilled at conducting this experiment.
- (8) I know somewhat more than most users about conducting this experiment.
- (9) How would you rate your skill at conducting this task, compared to other things you do on the computer?
- (10) I can use surgical tools to control objects in experimental environments.
- (11) The objects in VR environments are more controllable.
- (12) Do you think you have ever experienced flow during this experiment?
- (13) Most of the time I conducted this experiment I feel that I am in flow.
- (14) Overall task goals were presented in the beginning of the experiment.
- (15) Overall task goals were presented clearly.
- (16) Intermediate goals were presented in the beginning of each scene.
- (17) Intermediate goals were presented clearly.
- (18) I understand the learning goals through the experiment.
- (19) The experiment increases my knowledge.
- (20) I catch the basic ideas of the knowledge taught.
- (21) I try to apply the knowledge in the experiment.
- (22) How inconsistent or disconnected was the information coming from your various senses?
- (23) How much did your experiences in the virtual environment seem consistent with your real-world experiences?
- (24) I give myself pleasure by conducting this experiment.
- (25) I can say that I particularly like this experiment.
- (26) I have a strong interest in this experiment.

Data Availability

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Consent

Written informed consent for publication was obtained from all participants.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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