Original Article

Using Multimodal Interaction in a Virtual Reality Thoracic Diagnostic Scenario

Wen-Hsiang Lin[1], Wei-Kai Liou[2], Pao-Ju Chen[3], Sufen Chen[1],[2]

[1]Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taiwan [2]Empower Vocational Education Research Center, National Taiwan University of Science and Technology, Taiwan, [3]Department of Nursing, Asia Eastern University of Science and Technology, Taiwan

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Abstract

Background: Stethoscopes and mannequins are basic tools for medical practitioners to diagnose various problems. Restricted by space, resources, and time, these tools and common video training are sometimes inaccessible. These obstacles may be solved by immersive virtual reality (VR) that improves interaction and blurs the line between virtual and reality. Therefore, this study combines virtual and real interaction technologies to investigate the impact of multi-sensory interaction on learning outcomes in chest auscultation.

Methods: This study integrated VIVE Tracker technology to provide synchronized tactile stimulation in VR. University students in medical-related disciplines participated in the study. Interviews were conducted to understand how students perceived the effectiveness and usefulness of the thoracic auscultation VR.

Conclusion: Most students expressed that tactile stimulation gave realistic sensations and effectively reinforced the immersive effect. Simultaneously, it increased their interest and motivation in learning. The integration of synchronized tactile stimulation is a novel approach that expands the realm of interactivity beyond handheld controller manipulation and creates a platform to simulate medical-related scenarios to learn complex knowledge and skills.

Keywords: virtual reality, healthcare education, serious games, interactive learning, multi-sensory integration.

Introduction

This study aimed to develop a virtual reality (VR) system incorporating tactile stimulation to train medical students to detect and diagnose cardiac problems. The traditional training methods utilize 2D videos or drawings to explain the concepts and structures of stethoscopes, which are otherwise vague, invisible, and abstract to students. Moreover, stethoscope training requires many patients for practice. Cardiac sounds and mannequins are often used as substitutes; however, practice is restricted by these inconvenient and costly resources. Authentic VR could compensate for such restrictions. Previous studies showed that VR effectively contextualizes healthcare instruction and enhances students' skills.[1,2,3] Students prefer VR because it reduces external distractions such as noises and irrelevant environmental cues.[4,5]

Corresponding Author: Sufen Chen, Chair Professor, Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, 43, Keelung Rd., Sec.4, Taipei, 106335, Taiwan.

E-mail: sufchen@mail.ntust.edu.tw

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Furthermore, VR creates an immersive learning environment to engage students. Specifically, modern VR uses 3D scene creation tools such as Unity and Unreal Engine. These tools create lifelike visuals, including vivid lighting and textures with intricate object details. Through VR, students can immerse themselves in realistic medical scenarios, giving an engaging and focused learning experience.

In PC-based VR systems, users often hold controllers to manipulate virtual objects, such as grasping, rotating, and moving an item. This intuitive control method allows users to interact naturally with virtual objects. Moreover, devices, including cameras, infrared sensors, accelerometers, and gyroscopes, have been designed to track a user's position, gesture, and movement. These tracked actions can be synchronized with the agent so that the user experiences full-body ownership of the agent. The precise tracking increases authenticity and extends the control of users from hands to full body in VR.

Nevertheless, the potential of tracking devices in VR have not been fully realized. In fact, the majority of VR involves only auditory and visual senses. This study used trackers to stimulate a tactile sense. For example, the virtual and real stethoscopes are synchronized by attaching a tracker to a real-world stethoscope. Users can touch a real stethoscope and interact with the virtual stethoscope, providing a realistic and immersive simulation for medical students to practice auscultation skills. This approach enables previously untouchable virtual objects to become tangible. The integration of tactile sensations in virtual environments can enhance the feeling of presence and immersion in the virtual world[6,7,8,9] and thus is the focus of the current study.

The tracker technology enables students to experience both full-body movements and interactions in a virtual environment. They can move around and interact with patient models as they would in a real clinical setting. They would hear different lung and heart sounds when placing the stethoscope on various chest positions. These features provide a comprehensive and effective learning experience in medical education, as students can practice and refine their diagnostic and treatment skills in a safe and controlled environment.

A few studies have attempted to incorporate tracking devices into VR (e.g., Salagean et al.[10]; Škola et al.[11]). However, the designs might not be friendly to users. For example, Salagean et al.[10] had a complex experimental setup involving 77 markers, making the overall wearing experience considerably difficult for participants. Therefore, the current study looked for an easy-to-use and affordable solution using VIVE Trackers. The study examined if the auscultation VR training system could help students learn independently and effectively.

Materials and Methods

Development of a VR Learning System

This study conducted in September 2022 at the Nursing Department of Asia Eastern University of Science and Technology, involved 40 undergraduate students. The thoracic auscultation learning system built a virtual clinic scene using the Unity game engine, 3ds Max, and an HMD (HTC VIVE PRO STARTER KIT, 1440 x 1600 image resolution per eye, a large 110° field of view, and an ultra-smooth 90 Hz refresh rate). Eight VIVE Trackers were attached to the user's left and right hands, left and right feet, abdomen, table, chair, and stethoscope to enable them to interact with the virtual environment. Virtual settings and objects were created with a 1:1 size ratio between the virtual and physical worlds. Along with the movements of the stethoscope, the simulated sounds of a patient's heart and lungs were played through the headphones of the HMD.

Operating Procedures for the Thoracic Auscultation Learning System

- The researcher informed the subject of the learning objectives and how to use the VR learning system.
- The subject wore the VIVE Trackers on their hands (Figure 1), feet, and abdomen, as well as a HMD. Trackers were calibrated. The subject then started learning while sitting on a chair.

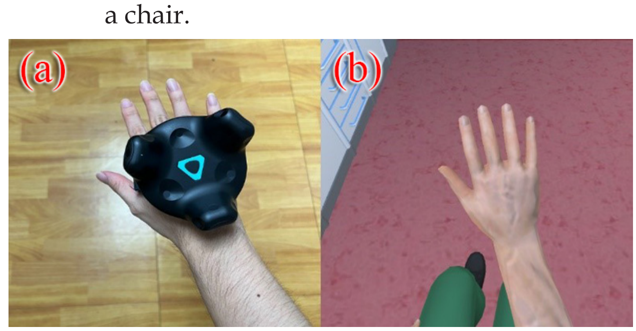

Fig. 1: Scenes of Real (a) and Virtual (b) Hand

- The subject entered the system to begin the interactive experience. A voice instructed the subject to raise their arms and select the operation exercise option from the menu (Figure 2).

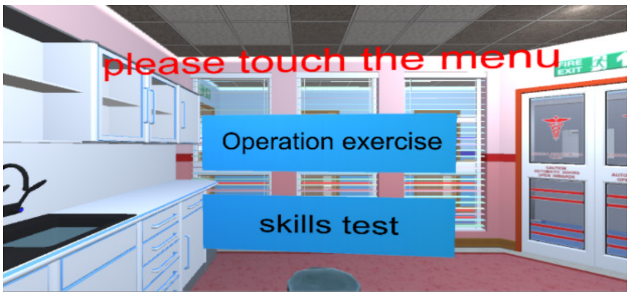

Fig. 2: System Start Menu

- During the operation exercise, the system showed dynamic arrows to prompt and guide the subject through the exercise steps.
- The subject practiced auscultation procedures on virtual patients in 20 distinct scenarios, each featuring different symptoms. Each scenario lasted approximately 3-5 minutes. When the stethoscope was brought close to the patient's chest (Fig. 3), they heard the lung or heart sound.

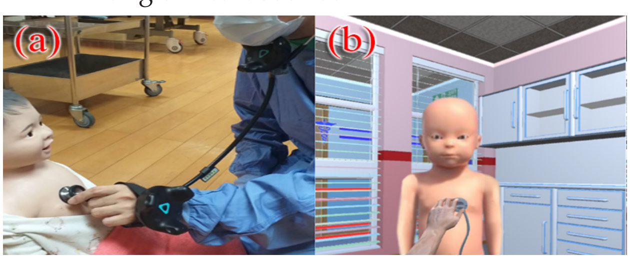

Fig. 3: Scenes of Real (a)and Virtual (b) Stethoscope

- After completing the operation exercises, the subject returned to the menu to take a skills test comprising 20 questions. The questions were in random order. This examination assessed their ability to identify various thoracic diseases based on the sounds they heard from the HMD. In order to provide the subject with a more immersive experience during the auscultation test, they would see patients of different ages (Figure 4)and genders.

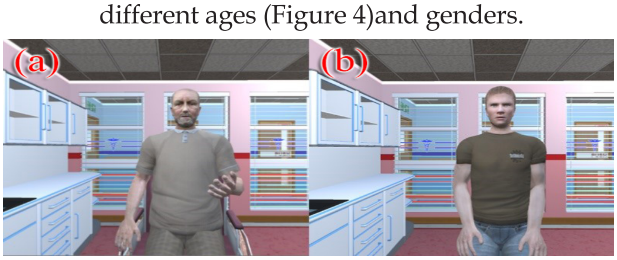

Fig.4: Scenes of Older (a) and Younger (b) Patients

- When the subject had answered all the questions, the score was displayed on the screen along with the questions the subject answered incorrectly. The subject could decide whether to review them.
- The subject had the option to repeat the skills test or exit the system.
- Trackers and HMD were removed.

Data Collection and Analysis

After all subjects completed the experiments, the focus group research method was employed to collect individual perspectives on the VR thoracic auscultation system. The subjects were divided into eight groups of five for the focus group discussions. During these discussions, we asked participants about their opinions regarding the use of VR in thoracic auscultation learning and their feedback on its benefits or drawbacks. Content analysis was applied to process the data and synthesize the key points into overarching themes.

Results

The results of the focus group discussion indicated that the students generally reported a positive impact from the system. They pointed out that the VR learning environment enhanced their learning interest, improved their learning focus, reduced learning stress, and fostered a more proactive willingness to communicate with patients. Furthermore, they provided recommendations for the design of the VR auscultation system. The following are some of the points the students raised in their group discussion.

VR Enhanced Learning Interest and Focus

Students' feedback revealed that operating a virtual human body in a VR environment provides a unique experience. They developed a sense of ownership over the virtual body, enabling them to immerse themselves in simulated clinical scenarios: "I felt as if I was in a clinic, operating the stethoscope like a nurse, and observing the patient's condition. This immersion sensation helped me focus more on learning auscultation skills" and "I fully immersed myself in the diagnostic scenario, and felt like a nurse responsible for performing the correct diagnosis for the patient, which piqued my interest in auscultation."

The ability to interact directly with the virtual world using their hands enhanced their interest in learning auscultation skills. This experience gave them a greater sense of control and involvement:"In VR, being able to use my hands directly felt very cool. I could perform various actions like a nurse, and this made the process of practicing auscultation much more fun."

VR Could Alleviate Stress but Trigger Uneasiness

Students' feedback revealed that the VR learning environment effectively provided a space with less social comparison and anxiety, thus helping reduce students' stress:

I often felt nervous and worried about making mistakes when practicing in front of my classmates. However, in VR, I couldn't see anyone else, and it boosted my confidence during practice.

I like this method of practice. I don't have to worry about others progressing too quickly, and I can control my own learning pace.

In a low-pressure learning environment, students found it easier to absorb knowledge: "Because there were no time constraints, I could focus on diagnosing patients, so it was quite relaxed during practice." However, VR could also trigger feelings of unease in students: "I found the patients in VR looked quite scary. Their expressions appeared very rigid and being stared at by them created a lot of stress." The students expected to have normal eye contact with the virtual patients.

VR Cultivated Communication Willingness

The VR learning environment facilitated students' engagement in conversations with virtual characters. Within this immersive setting, students honed their communication skills through interactions in various virtual patient scenarios, each presenting unique responses and challenges that static mannequins could not simulate. Therefore, students were willing to speak up, which enhanced their communication skills:

I felt like a nurse.The patients responded to my questions. This increased my willingness to communicate and assist patients.

VR feels real, and being asked to speak made me quite nervous. But it prompted me to reflect on my daily interactions with people.This experience made me realize the importance of communication.

Through interactions with virtual characters in a variety of test scenarios, this VR system enhanced my listening and diagnostic skills. It also alleviated my apprehension about speaking with patients.

VR Interactive Devices on Palms Were Uncomfortable

Student feedback revealed that how they wore VR devices could result in potential drawbacks, providing valuable insights into immersive learning. One student said: "Because the devices fixed on my hands made me feel uncomfortable, and using these devices during operations seemed somewhat unnatural, it distracted me from the VR environment. "However, the complaint was only about the hands. Hands are more sensitive than feet or the abdomen and so may induce a stronger unnatural feeling.

Discussion

As VR technology has advanced and has incorporated more sensory interaction features, students have become more immersed in the learning context.[12,13] This study added tactile sensations to virtual stethoscopes to enhance the immersiveness, which in turn further cultivated students' interest in chest auscultation. Our findings show the positive impact of tactile experiences in VR on student interest and focus.

Both this study and that of Moffitt et al.[14] suggest that VR alleviates anxiety due to social comparisons. Students can practice independently without worrying about their peers' learning speed. Specifically, VR could reduce the concerns of students who prioritize self-presentation or lack self-confidence. Gammage et al.[15] pointed out that such students often worry about receiving negative evaluations from others. In general, they learn in a more relaxed manner.

This study's multisensory experiences included not only stethoscope content but also the body movements and facial expressions of virtual patients. For nursing students, a patient's body language and facial expressions are crucial in non-verbal communication. Therefore, if virtual characters display rigid facial expressions, it could lead to feelings of isolation and discomfort, thereby increasing stress, especially in situations that require intense concentration on learning.[16] Likewise, the students emphasized the gaze of virtual characters. Improving eye communication with virtual characters, particularly the dynamic changes in gaze, helped reduce uneasiness in VR.

For medical students, effective communication with patients is an essential skill. Tactile feedback from virtual objects, such as medical tools, closely mirrors real-world experiences, creating a more immersive and realistic training environment.[17,18] The virtual environment provided opportunities to practice clear, accurate, and empathetic communication.

Conclusion

This research synchronized virtual and real-world objects for students to construct tangible learning memories through accurate tactile stimulation. The integration of visual, tactile, and auditory senses enriched the contextual learning experience in the virtual environment. Tactile feedback effectively drew students' attention to the learning content. This innovative approach promotes active participation and overcomes their nervousness. VR provides opportunities to practice conversations with virtual patients, thereby improving their communication skills.

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Informed Consent and Ethical Approval: This study was approved by the Research Ethics Committee of National Taiwan University, Taipei, Taiwan, with the registered number 202211EM013. As it is a regular teaching activity, we only used the developed teaching aids as a precursor test.

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