Disassociation of Visual-proprioception Feedback to Enhance Endotracheal Intubation

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***Abstract*—This paper discusses the key elements of a research study that focused on training an important procedure called "Endotracheal intubation" to novice students. Such a procedure is a virtual part of treating patients who are infected with the covid-19 virus. A virtual reality environment was created to facilitate the training of novice nurses (or nurse trainees) using the HTC Vive platform. The primary interaction with the virtual objects inside this simulation-based training environment was using the hand controller. However, the small mouth of the virtual patient and the necessity of utilizing both hands to pick up the laryngoscope and endotracheal tube at the same time (during training), led to collisions involving the hand controllers and hampered the immersive experience of the participants. A multi-sensory conflict notion-based approach was proposed to address this problem. We used "Haptic retargeting" method to solve this issue. And we compared the result of the haptic retargeting method with reference condtion. Initial Results (through a questionnaire) suggest that this Haptic retargeting approach increases the participants' sense of presence in the virtual environment.**

Keywords— Endotracheal intubation, multi-sensory conflict, surgical process, training.

I. Introduction

Loss of the patency of the airway is one most hazardous and life-threatening problems for human beings. Approximately 6% of these deaths are related to human airway obstruction [1].

Endotracheal intubation has always been a needed skill for many doctors and nurses. Seeing as it is "an airway management technique which is part of anesthesia procedure. In this procedure a tube is passed through the mouth into the trachea (windpipe) in order to maintain an open airway and provide artificial respirations [2]. This means that it is a procedure that helps patients breathe clearly in the event of an emergency, which became all the more prevalent during the height of the COVID-19 pandemic.

With all these factors in place, the need to train nurses and doctors in this procedure reached an all-time high.

Not only that, but a way for them to train without needing a physical model or building and minimalize human contact to prevent spreading of the pandemic became prevalent constraints as well. All of these factors combined saw the creation of endotracheal intubation simulators become a more prevalent subject of study these last couple of years.

Even before the pandemic, many researchers entertained these simulator ideas. Back in the year 2003, a researcher by the name of James Mayrose noted that; "The ability for a medical professional to practice a procedure multiple times prior to performing it on a patient will both enhance the skill of the individual while reducing the risk to the patient" [3]. He goes on to detail his research into creating the virtual head used to practice with and the other mechanisms to help make the simulation more accurate.

Another example can be seen in another paper written by Dr. Mayrose in 2007. In this paper, he not only expands his research from the prior experiments but also dives into the more medical aspects of these simulations. For example; "For the [simulator] to be effective, objects in the simulated environment must respond to the user's actions dynamically, in real-time, with accurate visual representations in regards to changes in geometry and appearance" [1]. Reading a patient's physiological reactions to whatever you are doing can help these doctors better determine how to help their patients.

Due to the fact that the Intubation process is a highly sensitive procedure and need a highly experienced anesthesia to do airway management procedure accurately and in a short time, it is still a big challenge to train nurses and anesthesia residents. [4] [5] [6]

The topic of VR simulators in the workforce has always been an interest for researchers and employers. The surge of VR technology that has come from this past decade has made these simulators more probable in practice and more practical in terms of efficiency. With more and more studies each day coming out about VR simulators, there is a definite possibility that more and more simulators will be implemented in professional environments.

Endotracheal Intubation is a complex substantial risk and difficult medical procedure. The skills needed to perform endotracheal intubation take a significant amount of training to have the experience needed to acquire the procession needed to successfully complete the procedure. During the medical procedure, an endotracheal tube will be inserted through the mouth into the trachea to optimize the patient's airway to provide necessary artificial respiration [1]. During the placement of the endotracheal tube, there is a considerable risk of causing scraps in the esophagus. which then can increase the risk of infection in the patient. To reduce risk, the doctor will use a laryngoscope to assist with the proper placement of the endotracheal breathing tube. Using the laryngoscope allows the doctor more visibility of the vocal cords, allowing for a safer, more consistent placement of the endotracheal tube. The doctor will then secure the endotracheal tube and ensure the airway is clear of obstructions so that the endotracheal tube can work properly.

Currently, the main training for Endotracheal intubation occurs on a cadaver or a medical manikin [2]. However, using plastic manikin increases the performance of the nurses by 35% [7] [8]. Meanwhile, virtual reality is a practical means to train medical staff [9].perivious studies showed that learning trough virtual reality is more effective in medical procedures. [10] [11] [12] [13]. For example, a virtual reality application in a medical procedure is laparoscopic surgery simulation, leading to shorter procedure time and incrementing the staff's performance [7] [14].

Over the past two decades, scientists have been fascinated by the possibilities that VR creates, whether for entertainment or professional work. VR gives the world a new platform to explore and create, thus making the desire to design simulations that can help train professionals using VR.

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The goal of this study is to present a fully immersive VR learning simulation that can allow for real-time feedback and accurate hand movements during the endotracheal intubation procedure. This simulation will allow the user to perform the endotracheal intubation procedure with the assistance of a laryngoscope and other necessary steps in a realistic virtual reality environment.

The sense of presence and immersion are two important factors of virtual reality. These senses in our simulation were compromised by a significant problem. In the medical procedure, endotracheal intubation is required to be done quickly and medical staff must use both hands to perform the procedure in the real world. However, in the virtual environment, due to the patient's mouth being small while the Vive controllers (joystick) are bulky, the controllers will bump together and ruin the sense of presence and immersion. To solve this problem we benefit from the idea of haptic retargeting [15]. According to this study visual input dominates proprioception feedback. By using this fact, we were able to find a solution to the bumping problem. We introduced a visual proprioception conflict model, by offsetting the position of the virtual hands from the real hands. This model allowed the virtual hands to be closer together while in the real world there was a small distance between them. Users were unable to notice this offset between the virtual and actual hands.

II. Method and Apparatus

A. Subject

Seven participants (4 males and 3 females aging range from 22- 36) took part in this experiment. Subjects from different backgrounds, either from inside or outside the university, agreed to participate voluntarily and without any compensation in the experiment. None of them had any physical or neurological disorders.

B. Experimental Device

Participants were standing in an empty and calm space during the experiment. They were equipped with an HTC Vive eye pro headset and controllers. The headset's resolution was 1440*1600 pixels per eye with 110 degrees of field-of-view. The device was equipped with eye tracking, a g-sensor, gyroscope, proximity, and eye comfort setting (IPD). The data output frequency was 120 Hz.

To collect physiological data we utilized the Empatica E4 wristband device. This device possesses PPG and EDA sensors, 3-axis Accelerometer, Infrared Thermopile, and Internal Real-Time Clock.

Fig. 1. Virtual surgical environment.

C. Environments

When a user wears the 3D headset, they are immersed in a simulation environment that replicates a realistic medical environment for practicing hooking up the patient to a ventilator. This environment contains multiple medical objects such as a surgical table, monitors, lights, etc (see Fig.1). There is a smaller table in the environment to the left of the user that has various medical tools on it, such as a laryngoscope, endotracheal tube, CO2 monitor, etc. To induce anxiety in the user we have added telephone noises, pager noises, as well as nurses who talk in the environment

D. Procedure

When participants entered the room we asked them to sit down for 10 minutes, this helped us gather stable physiological data. Then we asked them to wear the HTC Vive and enter the experiment in a standing position. Before entering, we briefly explained how the participant will receive instructions within the experiment. In the experiment, participants received instructions to perform the endotracheal intubation procedure. It starts by inserting the laryngoscope into a 3D model of a patient's throat, simultaneously they will insert the endotracheal tube into the patient's throat after visualizing the vocal cords with the laryngoscope. Once they have inserted the endotracheal tube into the patient's lungs, they will remove the laryngoscope and inflate the cuff at the end of the endotracheal tube. After this, they will apply a CO2 monitor to the endotracheal tube to ensure that the patient is breathing through the tube, and then hook the tube onto a holding mask to keep the tube in place.

E. Protocols

To measure the effectiveness of the haptic retargeting model, we provided two different scenarios.

Reference condition

In this condition, subjects did not perceive any visual proprioception conflict. Their virtual hands were aligned with their actual hand. The offset between the virtual hand and real hand was equal to 0. Participants did not perceive any conflict in this condition.

Conflict condition

In this condition, we changed the offset between the virtual hand and the real hand to equal 6 centimeters. This value is the best value that subjects could not perceive any disassociation between their virtual hand and their actual hand. However, the virtual hand was moving aligned with the real hand with the same velocity but in different positions.

F. Data and measurements

We utilized the presence questionnaire to measure the effectiveness of the haptic retargeting model in our experiment.

III. Data Analysis

Fig. 2, shows the mean value of the presence questionnaire for different 7 participants. According to this image, subjects sense more realism in conflict conditions compared to the reference condition. Moreover, subjects perceived more possibility to act in the conflict condition. However, the quality of the interface was almost the same in both conditions. Finally, they estimated in the conflict conditions they had a better performance and sense of presence.

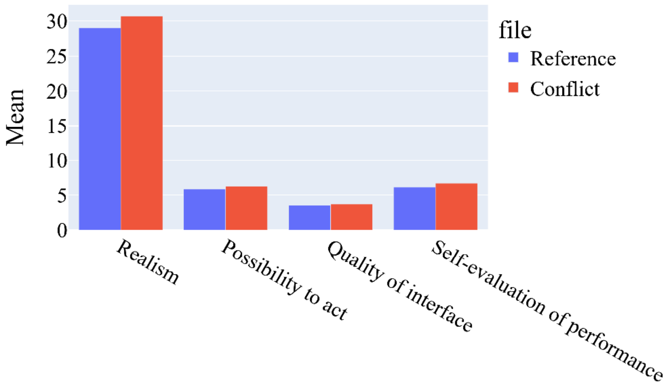

Fig. 2. Analysis of the presence questionnaire in different conditions.

IV. Discussion

The accessibility and usage of virtual reality in other fields of science, made scientists in different fields pay noticeable attention to the use of this application. One of the most sensitive fields of science is the medicine which requires a high concentration and low reaction time of the doctors and participants. Endotracheal intubation is one of the most sensitive procedure procedures in medical science which demands highly focused nurses and must be done in a short amount of time. Therefore, training nurses have special importance. Virtual reality by providing a realistic and believable environment is a good alternative solution to train novice medical students and nurses. In this study, we aimed to train nurses in the intubation process using virtual reality. To achieve this goal, we provided a surgical environment similar to the real one, and we asked novice people to join the experiment.

In the Endotracheal Intubation Simulation, there was a significant problem that affected the quality as well as the usability of the simulation. The problem is that when performing the simulation, the controllers end up bumping together and breaking the immersion. Two major factors caused this problem. The first is that the simulation requires you to have both hands in the patient's mouth at the same time. The second is that the HTC Vive controllers are significantly bigger than a hand. The simulation can still be completed despite this problem; however, it is much more strenuous and awkward.

The Solution to this problem that was implemented was setting an offset value to the virtual position of the controllers to the real-world position of the controllers. In most conventional virtual environments, the goal is to match the controllers exactly where they are in the real world. However, for the needs of our simulation, it was beneficial to make the virtual positions of the controllers closer together and offset them by a small but significant amount towards each other. We chose a distance close to this measure to make sure that users of the simulation would be unable to notice that the controllers were offset from their physical real-world positions. If the distances were too large that they would be noticeable, it would be incredibly disorienting for the user, however, if it was too small it would not be enough to fix the main problem described earlier.

The distance we found was a great compromise and was able to solve the main problem while keeping the offset hidden from the user. This solution was inspired by a concept called Haptic Retargeting, however, it differs moderately from the original concept, as it operates purely in the virtual environment and does not involve the physical world outside of the Vive controllers. Our results of the presence questionnaire confirm that by using this solution, participants experienced a better sense of presence in the environment, leading to better performance.

The solution we found was successful and is a technique that could be implemented in other Virtual Reality programs if those programs had problems similar to the Endotracheal Intubation simulation.

V. Conclusion

In this study, we tried to train naïve medical students who are at the beginning of their careers and need to train in a reliable environment without endangering the lives of human patients. Because most medical procedures are hard and mentally demanding, Virtual reality is a trustable and low-cost environment to train nurses and students.

In this experiment, we proposed a no-fee and simple coding base solution for solving the bumping hand controllers in VR. This solution is a great alternative to highly expensive solutions such as VR robotic hand gloves. This method can be used in other fields and applications of virtual reality. Using this method helps VR developers to enhance the sense of the presence of the user without using extra and expensive devices,

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