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Organ Donation Training using VR: ODT-VR

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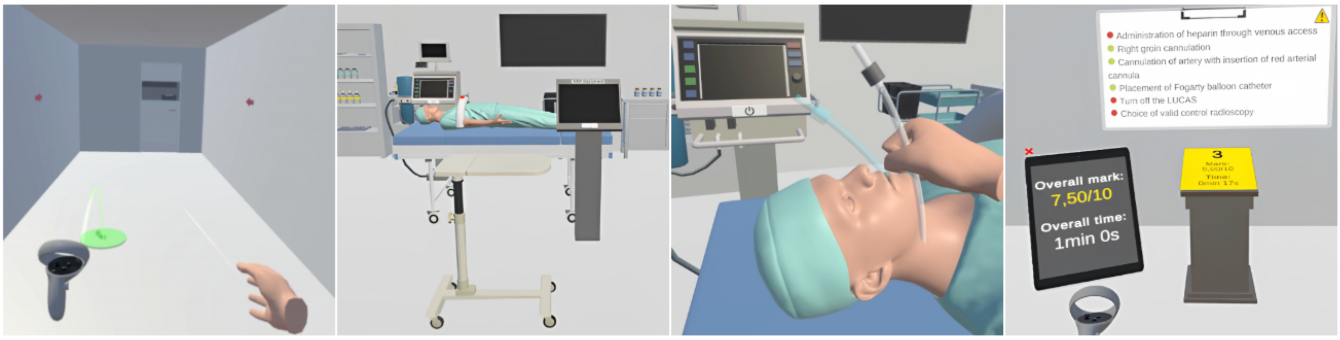

a) b) c) d)

Figure 1: *Application overview: Simulation of the medical protocol for the management of the Uncontrolled Donation after Circulatory detection of Death (uDCD). (a) Initial corridor, (b) main operation room with the donator and all the apparatus, (c) example of interaction with placeholder, (d) final evaluation room.*

Abstract

Organ transplantation has become very important for treating organ diseases and new technologies have been developed to increase the donor pool. Virtual Reality (VR) has been proven to be a valuable tool for training in medical education. This paper presents a VR application designed to simulate the medical protocol needed for the management of a deceased organ donation process called Uncontrolled Donation after Circulatory determination of Death (uDCD). Results from an explorative study on five medical experts in the area are presented, and future opportunities for improvement are discussed in the paper.

CCS Concepts

• ***Human-centered computing*** → ***Virtual reality;*** • ***Software and its engineering*** → ***Virtual worlds training simulations;***

1. Introduction

Organ transplantation has become the best, and in some cases the only, option for treating end stage organ diseases. Only 10 % of organ transplantation requirements are covered worldwide every year, making the scarcity of organs for transplantation a public healthcare issue. New techniques have been developed worldwide to increase the donor pool, including the controlled and uncontrolled Donation after Circulatory determination of Death (DCD). Cardiovascular disease is the main cause of death worldwide, making DCD a big opportunity for expanding the donor pool. By implementing these techniques, Spain and USA have become the world leaders in deceased organ donation. Unfortunately, only a few countries worldwide have been able to implement it. The Donation and Transplantation Institute (DTI) is a non-for-profit organization dedicated to improve the access to transplantation by transferring the expert's knowledge in organ donation and transplantation. DTI has been training professionals on deceased organ donation worldwide for the last 30 years, by performing face-to-face courses with simulation techniques called TPM course. Implementing VR solutions would greatly enhance the opportunities for more professionals to learn this technique and master it through repetition. It would also improve the access to these training while also decreasing the traveling costs for professionals.

In collaboration with Immersium Studio, DTI foundation created

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two VR experiences used through a mobile phone, called Family approach and TPM journey. In TPM journey, the user is guided through the organization of an organ donation unit inside a Spanish hospital. Family approach enables the viewer to act as a medical professional, with the objective of navigating the process of meeting a patient's family, learning about them and ultimately delivering bad news to the patient's family within the organ and tissue process. New digital tools such as VR allowed DTI to provide more individualized and realistic experiences.

The medical protocol for performing DCD requires decisions to be made in a restricted period of time. An error in those decisions may imply losing a donor or affecting the quality of the organs transplanted. Being able to train the skills and the procedure through an immersive experience would help train the physicians on a safe environment and facilitate their learning curve in a procedure that is not frequently performed. As far as we know, no tool using immersive technologies has been created for training the DCD technique, so in this paper we present a VR application to address this problem. The contributions of this paper are:

- An immersive VR environment to train users with the uDCD technique.
- An exploratory user study done by experts that evaluated the application and pointed out some improvements and extensions.

2. Related work

In recent years, the use of VR in medical education has increased a lot as can be seen in [KSW*19, PS18] where they shown how immersive technologies have been used in medicine for learning simple procedures and anatomy learning. Moreover, various applications have been developed for medical simulations and training. In the area of liver surgery, Chheang et al. [CSH*19] presented a collaborative VR environment for planning the surgery, helping surgeons to better identify and prevent potential complications, and improve surgical outcomes. In conclusion, digital representations of the human body are a valuable tool for healthcare professionals, and digital technology continues to evolve to provide increasingly accurate and effective tools for education and clinical practice. In fact, recent studies demonstrated that surgeons trained in VR improved their overall performance compared to their traditionally trained counterparts. They were also faster and more precise in performing surgical procedures [BZC*20, MSM*22].

3. Application Design and Implementation

Building an application to simulate the medical protocol presented above for training these skills to potential students required the knowledge and expertise of medical doctors experienced in this area. A DTI expert in deceased Organ Donation contributed with the medical content of the experience.The VR application needs:

- To simulate the steps included in the protocol for managing a uDCD donor in the most realistic way.
- To allow the maximum possible interaction by the user to potentiate the decision making.
- To provide feedback on the user for enhancing the learning process at the end of the experience.
- To follow up performance indicators that allow measuring the improvement on the expertise through repetition.
- To be immersive: We want to simulate as much as possible the feeling of being in an Emergency room and the interaction with the patient, so a fully immersive VR technology (HMD), such as a Meta Quest 2, is chosen.

Trying to fulfill all the requirements presented above, we developed an application that allows students to perform all the steps planned in the uDCD protocol. It allows users to interact with the environment using different standard interaction paradigms reaching an interaction as natural as possible. The application is focussed only on the steps required in the uDCD protocol, so it is not asking the user for specific medical procedures, like make an incision or inject a syringe. These procedures then are only represented symbolically and do not enter into a realistic simulation.

When starting the application, the user will appear at the hospital entrance (see Figure 1 (a)) and a voice will introduce them to the application. Once the voice has stopped talking, the user will be asked to move to the operation room. When the user is in the operation room (see Figure 1 (b)), the uDCD protocol starts. Here, the user has to complete a series of actions to simulate the given protocol. An action consists of user interactions with an object. For instance, an action could be pressing a button, grabbing an object or placing an instrument somewhere. When the user performs any of the actions, it can have two outcomes: correct or incorrect with an appropriate sound.

At the end of the protocol the user is automatically teletransported to a different room, the *Evaluation room*, where users can review their actions and results from each phase. The user appears at the center of room surrounded by podiums (see Figure 1 (d)) which represents each of the main phases (four phases) of the uDCD protocol. In front of each podium a board displays the actions carried out in that phase, with colored circles indicating correctness and a warning icon for additional details. The front of the podium shows the phase number, score, and time taken, with a background color reflecting the score's level.

Different interaction systems have been developed to simulate navigation and object manipulation. Each hand will be responsible for an interaction. The left hand handles movement, while the right hand handles object manipulation, each with a distinct 3D model. Figure 1 (a), shows left and right hand 3D models, respectively. As shown, a ray has been added to each hand. Next sections explain the main interaction techniques developed to allow users to interact with the virtual environment.

We used Unity (version 2021.3.12f) and the *XR Toolkit Interaction 2.0.2* package to enable interaction and controls in the VR environment and *Python for Unity 7.0.0* for the conversion of text to audio in the application. To find 3D models different websites were used: *Sketchfab*, *Turbosquid*, *CGTrader*, and *Mixamo*, and we also modeled the rest of the equipment by using simple 3D objects in order to facilitate the required interaction with the user.

3.1. Navigation techniques

Although the user can freely move around the virtual environment by walking, two standard controller-based techniques have been developed to facilitate the navigation without the necessity of user movement. We have to take into account that the real scenario of execution could be an office or a reduced-free space room, so, offering a navigation technique is mandatory. Following this requirement, the application offers the possibility of using *teleport* as a discrete navigation and also a continuous navigation that simulates the standard navigation technique using a joystick and buttons.

3.2. Object manipulation

As mentioned earlier, the tasks (or actions) performed by the user imply grabbing some object (for instance, a syringe) and put it in a specific place (for instance, the shoulder). In order to allow the user to perform this kind of interaction, two different techniques have been developed: directly by hand and also using an standard ray-based technique [BH99]. Moreover, for facilitating the user to know where to put an object, a visual cue is shown when the virtual object is very close to the right place determined by the medical expert (see Figure 1 (c)). Besides this direct actions, when the user is performing the tasks, different machines have to be switched on/off in different times. These actions are simulated by directly detecting the collision of the right hand with the corresponding 3D object representing the button.

Apart from the manipulation of 3D objects, the protocol requires sometimes to answer questions or show to the user some additional information. To do this the application includes a 3D object that represents a tablet, positioned on the left controller. In figure 1 (d) we can see the tablet being used in the last evaluation scene providing the total execution time and average score assessed. To ensure that the user notices when the tablet appears and requires their attention, a slight vibration is triggered on the left controller each time the tablet becomes visible.

4. Exploratory User Study

We conducted a usability test with five experts on the subject, members of the DTI. The user study has been designed to assess the participants' motivation, presence, immersion, and the learning outcome with the use of the application. This helped us to identify problems and areas for improvement. We wanted to assess not only ease of use and experience but also the different systems that have been developed for navigating and grabbing objects.

4.1. Study Design and Procedure

To carry out this study, three different questionnaires have been used. The usability of the application was evaluated using the System Usability Scale (SUS) [Bro95]. In addition, presence has been evaluated using the iGroup Presence Questionnaire [ipq], which evaluates three different aspects of the application: spatial presence, involvement, and experienced realism. Moreover, we added an additional and more specific questionnaire to assess the qualitative aspects of the different components of the application. The questionnaire is based on 25 questions and is carried out using a 7-point Likert scale (a summarized version is shown in table 4.1).

As explained before, participants were chosen from the DTI foundation members, focusing on those who have the medical

Aspect	Category	Question
General	Application	I experienced some physical symptom
General	Application	I would use it as a student
General	Application	It was fun to work with it
General	Application	The application is useful for education
General	Application	VR can enhance the learning effect
General		Sound effects were appropriate
Utility	Evaluation	The evaluation room was helpful
Utility	Evaluation	The explanations of the evaluation room were enough to learn from mistakes
Sickness	Teleport Joystick	I felt disoriented when using it
Utility	Teleport	I always move where I planned to
Sickness	Joystick	I felt dizzy when using it
Ease	Teleport Joystick	I found it easy to use or to move
Ease	Teleport Joystick	I found it easy to understand how to use
Utility	Ray-Hand	I found it useful
Comfort	Ray	I felt awkward grabbing from the distance
Utility	Ray	Color coding was intuitive
Ease	Ray	I found it useful to interact with the tablet
Ease	Hand	It was difficult to grab
Comfort	Hand	It was useful using the ray for the tablet
Utility	Tablet	I found it useful
Ease	Tablet	I know what to do
Ease	Tablet	I know how to activate it
Comfort	Tablet	The content was clear and understandable

Table 1: *Summarized version of the questionnaire focused on evaluating different aspects of the application.*

knowledge, who have experience on organizing the training or belong to the training department. When the participants arrived, we informed them about the objective of the test and about the technology used and its potential risks. Then, with the help of different videos of the application, we introduced them about the main aspects of it: the different components, how to interact, etc. After that, the experimentation with the application started. Lastly, the participant had to complete the aforementioned questionnaires.

5. Results

According to the SUS questionnaire (answered on a 5-point Likert scale), our application achieved good usability (Score = 84.17%). Regarding IPQ form results (1-7 Likert), the average score for spatial presence is 5.8. Involvement received an average score of 6.33. The realism factor has the lowest score of 5.33. Lastly, the control factor has a score of 6.08. With respect to the questionnaire devoted to the qualitative analysis of the application, we determined four different categories to evaluate: navigation (Teleport and Joystick), object manipulation (Ray and Hand) , the tablet virtual device (Tablet) and the evaluation phase (Evaluation). These categories represent the aggregation of participants' responses regarding their level of agreement with various aspects of the application. Regarding navigation, teleport received a higher score than the joystick navigation, with scores 6.45 and 4.6, respectively. For the case of object manipulation, the ray received a score of 5.53, lower than its counterpart, the hand, which received a score of 6.33. Finally, the tablet and evaluation received scores of 5.85 and 6.02, respectively. Figure 2 shows the usability for the different interaction systems used. This usability is obtained by calculating the mean of the scores received for each question for each aspect of the application. On the other hand, table 2 shows the average score for different aspects, each of which is evaluated through some specific questions from the questionnaire related to that aspect.

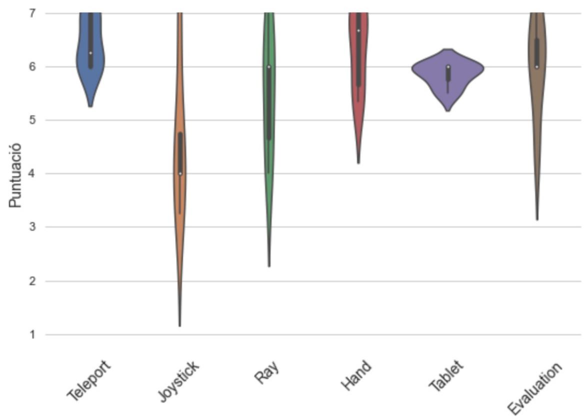

Figure 2: *Violin plot showing the usability for the categories.*

	Teleport	Joystick	Ray	Hand	Tablet	Evaluation
Ease	6.5	5.2	5.8	5.13	5.67	6.0
Comfort	6.4	4.0	4.5	6.8	5.3	5.8
Utility	6.4	5.6	6.0	6.4	6.4	6.2
Sickness	1.6	4.0	-	-	-	-

Table 2: *Average score for the different aspects of the application.*

The application was rated positively in terms of usability, enjoyment, educational benefits, and its potential to enhance learning compared to traditional methods. It received an average rating of 8.4 in a scale from 0 to 10.

Some participants provided feedback and suggestions to enhance the virtual environment, including the incorporation of additional elements to enhance realism, such as adding a sharps container. It is noteworthy that two out of the five participants experienced dizziness specifically when using the joystick for navigation. However, when they were provided with a chair to sit down during the experience, they no longer reported any dizziness. This observation aligns with our initial considerations, as the joystick technique is designed to be used in a seated position, considering the absence of physical space.

6. Discussion and Conclusion

Immersive technologies would hardly replace the traditional methodology for learning new practices in organ donation. Nevertheless, the utility of these technologies could rely on providing a platform for improving the performance by continues practice, creating different scenarios where infrequent complications may be replicated, and sustaining the knowledge in those procedures with a lower incidence.

With a score of 84.17 on the SUS scale, our application can be considered to have high usability. The results showed a satisfactory level of presence and a high level of involvement. However, the realism of the virtual environment received a lower score, indicating some perceived limitations in resemblance to reality. The users experienced a good level of perceived control over actions and interactions within the application. However, based on the results from table 2, it can be observed how comfort varies depending on the interaction system with objects. This value, along with the inherent human nature of grasping objects with the hand, could explain why users consistently used their hand to pick up objects.

In conclusion, the results of the evaluation indicate that the application has high usability, positive user perception of presence and involvement, and potential for educational benefits. However, there are areas that can be improved, such as the realism of the virtual environment and the usability of certain interaction systems. Incorporating user assistance or guidance during the application's use could enhance the overall experience.

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