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MR-NRP: Towards A Mixed Reality Simulation for PPV Training in Neonatal Resuscitation

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Abstract

Mixed Reality (MR) introduces many possibilities for interacting with virtual environments in which training could be provided for some life-saving critical tasks. Neonatal Resuscitation is one of these tasks that would benefit from having a safe and immersive environment for practice. In this paper, we introduce an MR-based simulation that is aimed at healthcare practitioners to practice Positive Pressure Ventilation (PPV) in an immersive, risk-free, and interactive way using the hand-tracking capabilities built in the Mixed Reality Head Mounted Display. This research moves towards providing a standard addition to the neonatal healthcare system where MR could facilitate refresher sessions for the neonatal resuscitation procedure and eventually allow practitioners to assess their performance during the simulation. The simulation is based on a Virtual Reality (VR) Neonatal Resuscitation Program (NRP) simulation and is designed to rely on and utilize MR elements and features. We propose that this simulation could be used to receive refresher training sessions that would take place between the regularly scheduled in-person training sessions.

Introduction

Approximately 2.4 million newborns died in 2019, with birth asphyxia being one of the leading causes of neonatal deaths [8]. Well-trained staff capable of performing neonatal resuscitation is one of the most effective methods to counter this, as there is little room for error during the procedure. Neonatal resuscitation training was found to reduce term intrapartum-related deaths by 30% [5]. Exposure to events requiring neonatal resuscitation skills may not be common in real life, leading to skill deterioration over time [2]. Frequent training sessions and mock procedures could prevent this deterioration [2], but access to regular in-person training may not be feasible for all healthcare providers, especially in rural areas where it can be less accessible.

Computer-based simulations provide a cost-effective and safe training method using software that simulates medical scenarios without compromising patient safety. Extended Reality (XR) systems, which include virtual, mixed, and Augmented Reality Systems have been shown to create a higher sense of immersion than traditional simulations [4]. In these, Head-Mounted Displays (HMDs) are typically used to allow providers to immerse themselves in simulations while walking and moving their hands, offering a greater sense of control over their surroundings than desktop-based computer simulations. This novel approach enhances the learning experience, engages providers, and improves skill retention [3]. XR simulations are particularly effective in the retention and acquisition of cognitive and psychomotor skills due to the provider's interaction with the environment [4].

This paper involves the development of a prototype for the Meta Quest 3 Head-Mounted Display that utilizes MR to provide a simulation for neonatal resuscitation training, with the aim of providing an accessible and effective way for health care providers to practice and develop their NRP skills. This work is based on a previously developed VR-NRP simulation that was developed for the HTC Vive HMD as part of an exploration into the use of VR for NRP [1]. As part of this project, we have ported the VR simulation to the Meta Quest 3 and overhauled it towards an MR implementation.

Methodology

Device and Game Engine

For this project, Unity 3D was used for the development since the original VR simulationwas developed using Unity. A detailed description of the development process can be found in the work of Aydin et al. [1]. Additionally, Unity supports cross-platform XR development, which can be helpful if the project needs to be deployed to additional platforms.

Meta Quest 3 was used as the HMD for this project since it is one of the most advanced HMDs that are relatively accessible to consumers and supports XR, unlike the HTC Vive, which was used for the original VR-NRP simulation and only supports VR. The Meta Quest 3 comes with two controllers like the HTC Vive. In this project we aim to improve the usability of the systemby having providers execute the simulation using their bare hands to navigate through the simulation and interact with all the elements of the simulation instead of the controllers. This is done by using the native hand-tracking capabilities of the Meta Quest 3.

Environment and Rooms

Similar to the work of Aydin et al. [1], the simulation consists of three rooms. The first room the provider starts in serves as a lobby in which the provider can get used to how it feels to be in an XR environment. There is not much interaction that happens in this room, as it was developed as a starting zone where the providers can get ready for the simulation and become familiar with the VR environment and the navigation options.

After getting familiar with the starting room, providers are invited to try the next room, which is the "Tutorial" room. In this room, providers can get familiar with the interactions they will be experiencing during the simulation. The main objects in the environment of the tutorial room are the: 1) Baby, 2) Doctor avatar, and 3) Bag mask. These items serve to train the provider to interact with the simulation without a specific script or scenario to follow. Here, providers can spend as much time as needed to become familiar with all the controls and interactions.

The third and final room is the "Simulation" room. In this room, providers are taken through a scenario in which a baby is delivered with complications that result in the need to start the neonatal resuscitation. The main objects in this room are: 1) Baby, 2) Doctor Avatar, 3) PPV device with mask, 4) cardio-respiratory and pulse oximetry monitor, and 5) NRP algorithm, Target Oxygen Saturation Table, and MR.SOPA posters.

The environment of the room is shown in Figure 1. The types of interaction in this room are the same as in the tutorial room, except there is a specific scenario to follow here, with the doctor avatar giving instructions and guidance throughout the simulation scenario.

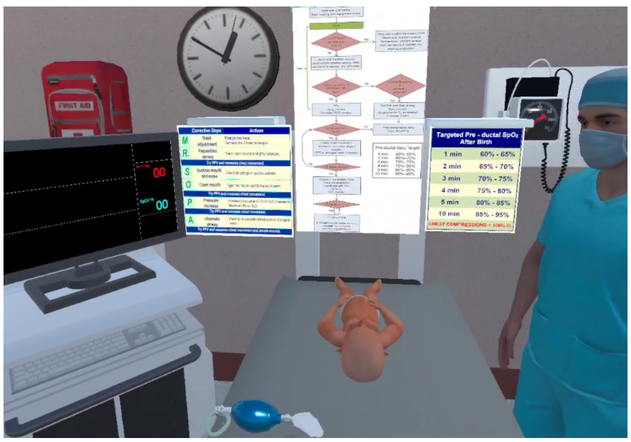

Figure 1. *Simulation Room Environment*

Controls

For the original VR simulation, VR controllers were used for interactions because such controllers are one of the most widely available mechanisms for providing input in VR. However, this MR implementation of the simulation aims to be more realitic and accessible. Accordingly, all interactions have been adapted to utilize pass-through and hand-tracking technology, which incorporates real-world input for interacting with the simulation. The controls in the simulation are divided into navigation controls, which allow for navigation between the three rooms and within the rooms themselves, and PPV controls, which pertain to performing PPV on the baby, whether in the tutorial room or in the simulation room.

Navigation

Navigation within any room is performed by the provider moving around in the real world, which in turn, thanks to the sensors in the HMD, will translate the provider's movement into the corresponding location within the simulation's virtual space. In this simulation, providers do not need to move around, mostly due to the fact that they are initially positioned at locations that are already within reach of everything they might need to interact with.

In addition to navigation within a certain room, providers can also go to different rooms within the simulation. This is achieved by opening a menu panel and selecting the room of interest. After that, providers are teleported to the room of their choice.

Since we have chosen all interactions with the VR environment to be done exclusively through the built-in hand-tracking mechanism, instead of pressing a physical button on a VR controller to open the menu responsible for navigation, the providers must perform a specific gesture and touch a button that appears when the pinch gesture is performed. This is shown in Figure 2. A successful pinching of the sphere will open the navigation menu, from which providers can also choose an option by touching a button to be teleported to the corresponding room based on their choice, as shown in Figure 3. The navigation menu includes three buttons: The "Tutorial" button will transport the provider to the Tutorial Room, the "Start" button will transport the provider to the Simulation Room, and the "Exit" button will transport the provider to the first room where the provider starts the simulation.

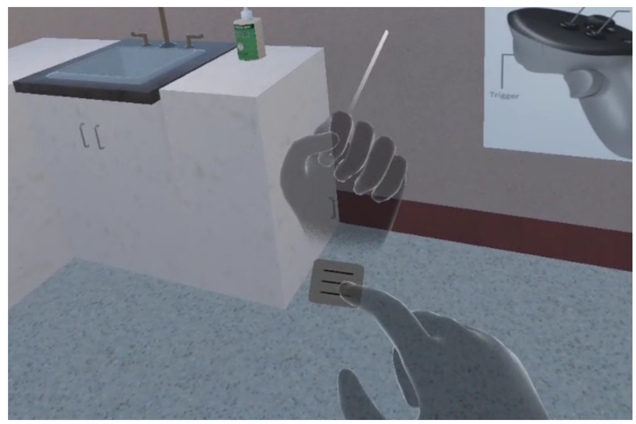

Figure 2. *Gesture to show navigation menu button*

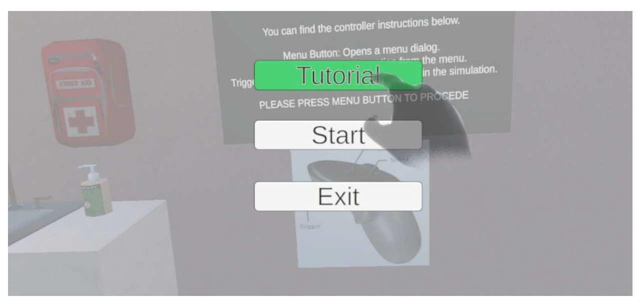

Figure 3. *Navigation menu*

Positive Pressure Ventilation (PPV)

Positive pressure ventilation techniques are crucial in the delivery of neonatal resuscitation [7]. Accordingly, moving from using a controller-based control scheme to hand tracking-based is expected to lead to a more effective training method since it can now include the hand motor skills that are used in the actual procedure. In order to deliver positive pressure ventilation in either the tutorial room or the simulation room, the provider starts by holding the virtual bag mask in the simulation simply by pinching with their left hand close to the "mask" part of the bag mask. This secures the bag mask in their hand so that the fingers are on the face mask, which simulates a common way to hold the mask against the infant's face to minimize face mask leak during PPV. This is known as the "two point top hold" [6] or C-E grip, as shown in Figure 4. Next, the provider can move their hand towards the virtual infant's face in order to move the bag mask. Once the mask gets close enough to the infant's face, it will snap in place over the infant's chin, mouth, and nose, as shown in Figure 5. Finally, once the bag mask is in place, the provider can begin to deliver PPV by moving their right hand towards the PPV device and squeezing using their thumb, index, and middle fingers as shown in Figure 6.

Figure 4. *provider is holding and moving the bag mask.*

Figure 5. *provider is placing the bag mask on the infant's face*

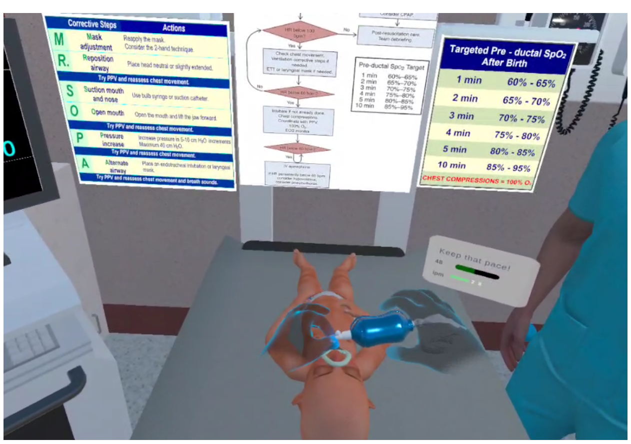

Figure 6. *provider is delivering PPV to the infant*

Simulation

Since the simulation is in MR, we plan to give the provider the ability to integrate an infant manikin and an actual bag mask to include haptic (tactile) feedback to help make the training process more realistic. Accordingly, the simulation starts by asking the provider to choose a surface to operate on. This is the surface where the infant will be placed; these surfaces are mapped by the headset according to surfaces in the real world in the initial setup of the HMD within the actual workspace. One of the real-world surfaces will be used such that the virtual warmer in the simulation will be located. The location of the warmer will also be used to determine the location where the infant will appear. The provider chooses a surface by tapping to the left and right side of where they would like the head of the infant to be on this surface. After the provider has completed this process, the virtual infant appears at the chosen location, and the simulation room appears around it. This process is shown in Figure 7.

After the room is developed in the VR, the provider is then taken through a realistic scenario in which they need to deliver PPV as indicated during this scenario. During the times at which the provider is delivering PPV, a pop-up dialog appears on their right hand with a progress bar that has been designed to guide them with the proper rate of ventilation, 40-60 breaths/inflations per minute (or squeezes of the bag per minute) through some visual hints. For instance, there is a prompt that lets the provider know if they are going too fast or too slow, a bar to tell them approximately how fast or slow they are going, the ventilation rate per minute, and a sequence illustrating the rhythm to follow when squeezing the bag. This is shown in Figure 6. This visual guide is based on NRP recommended PPV ventilation techniques, which are aimed on ventilation rates of 40-60 breaths per minute [7].

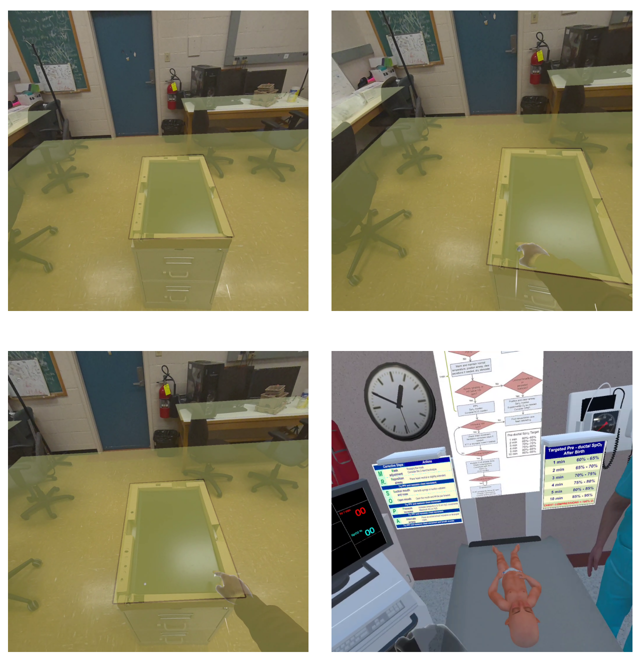

Figure 7. *Sequence of steps to trigger the simulation room to appear around the chosen surface*

Discussion

This research introduces a solution towards a Mixed Reality (MR) simulation with the purpose of training healthcare providers in the delivery of Positive Pressure Ventilation (PPV) for neonatal resuscitation. This simulation aims to develop an immersive, risk-free, and interactive training platform that can be integrated into the neonatal healthcare environment. It builds upon a previously developed Virtual Reality (VR) simulation, adapting it to the Meta Quest 3 device. It leverages AR elements for enhanced interaction, such as hand tracking, to make the simulation more natural and effectively train hand motor skills. It aims to provide haptic feedback with the goal to eventually incorporate real-world manikins and PPV devices to improve the training process.

The original neonatal resuscitation platform on which this simulation was built utilized virtual reality as a way to immerse the provider in the environment and deliver a more authentic experience that is closer to traditional training. However, one limitation of that approach is that the training of the hand motor skills employed in the positive pressure ventilation process is neglected due to the fact that providers have to trigger a button in the VR controller to simulate the hand and finger movements during the procedure. This limitation is now addressed through the use of hand-tracking technology. This allows providers to have a more lifelike involvement when it comes to controlling the positive pressure ventilation aspect of the procedure.

The utilization of hand tracking technology provides a more authentic and lifelike experience for providers, who can focus more on the acquisition and development of hand motor skills for delivering effective positive pressure ventilation. In the near future, we are planning to add the option of operating on a real manikin using a real bag-mask for haptic feedback to improve the training experience and effectiveness. The addition of mixed reality elements into the project aims to elevate the training experience for providers. In addition, we are aiming at developing features to be able to provide refresher sessions to take place multiple times between the two-year periods regularly scheduled for in-person training.

One of the limitations of this work is the accuracy of the hand-tracking technology when used with an actual bag mask for haptic feedback. Depending on the provider, some might hold the bag mask in a way that might cover the fingers, making it difficult for the hand-tracking camera to track parts of their hands. This could be addressed by instructing providers on how to squeeze the bag beforehand. Another limitation is that people who are susceptible to motion sickness might find the simulation difficult to use, since it is known that Virtual Reality systems can induce motion sickness in some users.

In the near future, we are planning on conducting a user study to measure the effectiveness of this solution in comparison to the Virtual Reality solution. Items that we are planning to measure include immersion, presence, ease of use, intuitiveness, and confidence in positive pressure ventilation skills before and after experiencing the simulation. The simulation could also be extended into a multi-user system to include observers whose job would be to witness and/or assess the effectiveness of the provider. This could be supported with performance indicators from the simulation such as the percentage of correct bag inflations and the percentage of time spent within the correct range of inflations per minute. With further development, this simulation could become a prototype of an end-to-end training and evaluation process for healthcare providers for positive pressure ventilation in the neonatal resuscitation program.

Conclusion

The proposed Mixed Reality simulation offers a potential approach to provide neonatal resuscitation refresher training sessions as it combines the immersiveness of Virtual Reality with the accessibility and practicality of hand-tracking, resulting in a more lifelike approach to positive pressure ventilation. This research aims to provide an accessible and cost-efficient way of providing NRP refresher training sessions for healthcare providers. This will be especially helpful for rural areas where resources are limited or areas with geographical barriers that hinder in-person training, which raises the cost of training. Further evaluation of this simulation through experimental user studies will assess its impact on skill acquisition, retention, and overall neonatal healthcare outcomes.

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