Developing an AR Environment that Allows Intuitive Interaction and Enhances Communication During Resuscitation Procedures

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Fig. 1. Pediatric resuscitation simulation taking place at Cornell Weill Medicine's Emergency Pediatric Department.

Effective collaboration among healthcare workers (HCWs) is essential in time-sensitive environments, as bedside care challenges can increase stress levels and negatively impact patient care. To address this issue, we aim to introduce augmented reality (AR) to HCWs using head-mounted displays (HMDs) to enhance collaboration with seamless interaction and efficient task management. To aid team leaders' task management, we intend to provide virtual visual cues for action coordination in simulation training to determine their

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efficiency in a staged resuscitation event. We will measure self-reported team collaboration, cognitive load, and system usability to evaluate the effectiveness of our AR prototype. We anticipate our results to enhance team collaboration, reduce cognitive load, and streamline task management, improving HCWs' working environments and patient outcomes.

Additional Key Words and Phrases: Augmented Reality, Healthcare, Collaboration, Task Management, Resuscitation.

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1 INTRODUCTION

In healthcare settings, healthcare workers (HCWs) are consistently communicating with one another while performing bedside tasks. With high levels of collaboration and multi-tasking, it is not uncommon to see errors and stress arise due to miscommunication and task interruptions. It is recognized that there is a positive relationship between high levels of burnout among HCWs and a patient's condition worsening [8]. To address this, HCWs have been introduced to several methodologies that could support them. Methods include the well-known steps of closed-loop communication; in some procedures, it could be the physical support of instruction cards. However, closed-loop communication is not always performed, nor are instruction cards always used as they have demonstrated to be extra steps that HCWs need to adapt to in order to validate their performance [4]. Our study aims to introduce a methodology that provides seamless interaction using an advancing technology, augmented reality (AR).

AR is a system that could benefit HCWs as it is smart glasses that display virtual objects, providing additional information to support a user's decisions during a procedure. AR has been utilized in several fields of healthcare, including telemedicine [16], educational training [20], and multi-user collaboration [13]. While in these fields, there are two primary ways to provide AR, including through mobile devices and head-mounted displays, similar to a helmet with a small display optic. Our initial work will observe how to best display and create these intuitive actions by collecting feedback from experienced HCWs on the designs for providing procedure instructions, task summaries, timers, patient background, and even dosage amounts. We will later observe how AR through HMDs can support task management more intuitively using virtual displays to recall users' tasks in a user study.

1.1 Contributions

(1) We will first conduct a design study to assess the flow of our AR designs and make alterations based on HCWs' feedback.
(2) We will observe the results of assistive task management for healthcare workers using the HoloLens 2.
(3) We will compare collaboration efficiency between AR and No-AR users.
(4) We will explore the preferred multimodal data the HCWs deem high-quality for seamless interaction.

2 RELATED WORK

Successful teamwork is critical in time-sensitive procedures because they need a pre-operational structure and the availability of role assignments. As seen in the operating room (OR), team leaders assign roles and tasks based on familiarity with role behaviors and in the order of staff arrival, [14]. To assess one's familiarity with role behavior while vocalizing tasks to prevent assumptions, closed-loop communication (CLC) has become an adapted methodology [22]. In addition to announcing roles, a team leader is required for effective communication and performance to guide procedural tasks and support CLC for patient safety and timely updates for staff [1]. Further, a team leader must memorize task assignments to manage efficiently to avoid overlapping charges [23]. Thus, efficient teamwork is rooted in structured teams, starting with an active team leader; however, if the team leader undergoes a high cognitive load, this could impact team performance. To help prevent an increase in cognitive load, we intend to address task management specifically for HCWs.

AR applications have been explored throughout healthcare departments including radiology [6], dentistry [21], and cardiology [18]. AR training has been observed in ORs, showing promise for future surgical navigation practice [15]. Whereas AR in telemedicine has demonstrated reliable and efficient virtual consultation within ICU centers [26]. Similarly, AR for telementoring in healthcare settings has improved task performance and completion time among HCWs [3]. However, more AR studies need to focus on task management as the root cause of poor collaboration among HCWs in a healthcare department. AR mobile devices provide virtual instructions [5], but noninvasive headsets need further exploration. We aim to promote future studies on AR through HMD for task management to improve collaboration among HCWs.

AR is a promising system for collaboration as it presents virtual objects to the physical world on multiple platforms, such as mobile devices and HMDs [2, 11]. These devices aim to produce limitless virtual objects to enhance a user's viewpoint of a scene with a screen that provides valuable information for further interaction. This results in virtual environments that can be utilized in a variety of settings, including healthcare, education, maintenance, and entertainment [2, 9–11]. With an extensive range of AR possibilities, many strengths and limitations have been identified with implementing AR HMDs. The strengths of HMDs involve providing captivating experiences for users that can appeal to multiple learning types due to their immersive features [9]. However, the limitations of HMDs are typically in the device themselves inducing cybersickness through low-quality headset comfort [11], poor computer displays [7], limited field-of-view (FoV) [17], and display lag [19]. It is essential to acknowledge that other studies have been capable of achieving reduced cognitive load even with the strengths and limitations of a HMD [12, 24, 25]. In this study, we intend to provide minimal but informational displays to reduce cognitive load and increase collaboration among HCWs.

3 ENVIRONMENT DESIGN

Most of my time during the DREU internship was devoted to the literature review summarized above in Section 2 and designing a high-quality virtual environment. To begin designing a high-quality environment, I became familiar with Unity and Mixed Reality Toolkit (MRTK) to use the virtual environment in a HMD. I had the opportunity to begin my DREU experience early, with the support of my lab at Colorado State University, where I started familiarizing myself with these applications before ultimately transitioning to Cornell Tech. I quickly learned Unity's platform thanks to my Unreal Engine experience and following online examples. With the primary goal of the virtual application being to provide a seamless interaction between the user and virtual objects, my focus was drawn to MRTK's interfaces. I decided to work with MRTK3 thinking that the most recent version would be the most reliable, but it wasn't until later that I learned about its lack of resources due to MRTK's team's lack of employees [27]. I devoted much of my time to the virtual application and decided to continue with MRTK3, transitioning only if I had to for person detection and recognition.

The current design of the virtual application utilizes three primary components, including opening a hand menu, selecting options from the hand menu, and relocating task icons. The hand menu is an MRTK3 feature that allows users to see a menu of buttons off the side of their hand only when looking at their palm. The seven available selection options fall into the three categories that will be further explained in Section 4.2. Once the desired button is selected

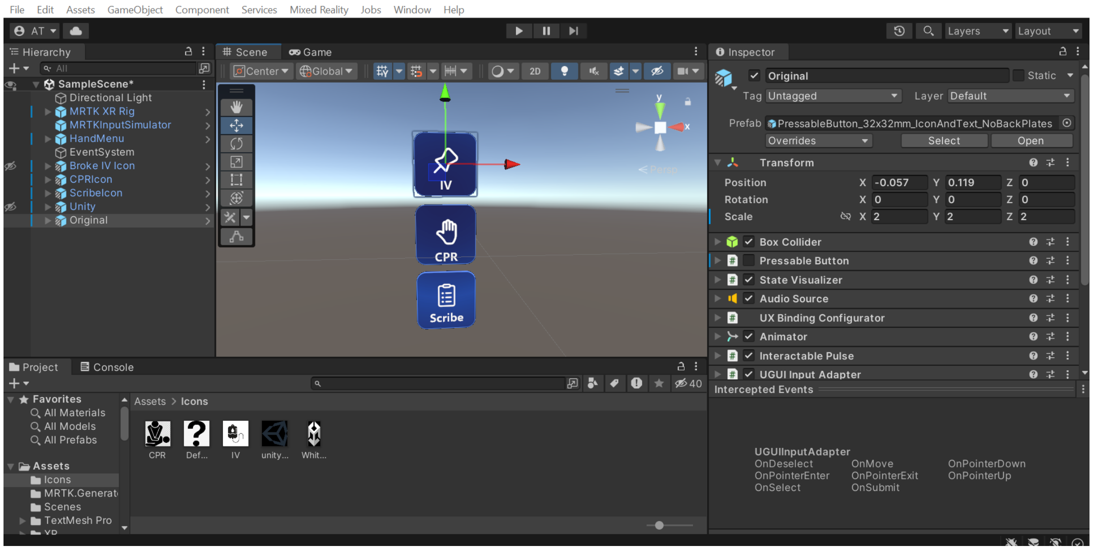

Fig. 2. A screenshot of the Unity software while working on the pilot study's virtual environment

from the hand menu, the corresponding task icon will be set to active and deactivated when chosen again. The task icon is draggable and is designed to allow users to relocate the virtual object above collaborators to help indicate which task they are performing to reduce duplicate task assignments and support the user's memory recall of assigned tasks. This manual virtual application is the current design we intend to use in the pilot study.

The initial goal was not to use a hand menu but to track collaborators and set them up as virtual buttons so that when interacted with, the virtual task icon could be displayed above the interacted-with individual, removing the need for manual selection and relocation. However, this would require additional software that cooperates with Unity and MRTK3 so that user detection occurs from the HoloLen's camera. Attempts to use the OpenCV application are in progress but may require us to adjust the virtual application to work with MRTK2 instead of MRTK3. There are additional concerns regarding collaborators leaving the user's point of view; the task icon needs to continue associating with the initially selected collaborator when they are back in sight. Although a lot of progress has been made with the interaction of the virtual environment, many details are becoming a concern in addition to human detection and recognition. As we progressed through the summer, we learned that HCWs are looking to do a lot more in their virtual environments, but this means increasing the flow of the screen not to overwhelm HCWs and disrupt patient care. We decided to change our plans from a user study to a design study to focus on gathering feedback from HCWs before implementing the environment in a simulation session.

4 FUTURE WORK

As the Distributed Research Experiences for Undergraduates (DREU) internship comes to an end, I have committed to continuing to work with both my Colorado State University (CSU) professor, Francisco Ortega, and my DREU assigned professor, Angelique Taylor, to finish the work I have started. We have since introduced another member who is a graduate student at Cornell University in Ithaca to help us tackle the people detection and recognition problem. I intend

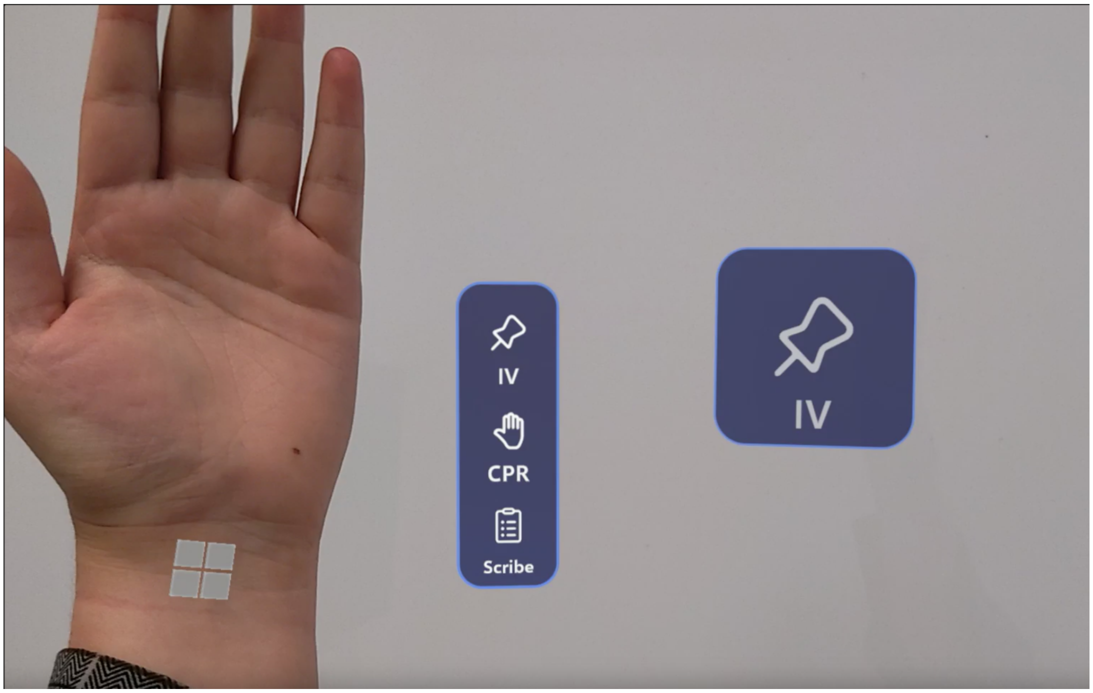

Fig. 3. Display from the HoloLens perspective with the hand menu and task icons making an appearance.

to continue refining the virtual application's user interaction features as we continue the design and user experiments described in the following subsections.

4.1 Design Study

Our group has discussed a lot of potential next steps and environment features that were initially considered to be included in the user study. However, with the overwhelming amount of possibilities, we decided to take a step back and gather more feedback from the HCWs, who will be the ones using the displays. Initially, we created task management options that would allow team leaders to visualize better what tasks everyone else in the room is performing. After attending simulations and hearing from similar projects, we recognize that team leaders want a lot more information, such as procedure summaries and timers, to help their task management flow. Additional features that could benefit the flow of procedures could be multi-user collaborators, where multiple individuals are wearing and interacting behind the lens of a HMD. Initially, a considerable part of our original design included robot operating systems, which could be connected to a crash cart while collecting verbal and visual data about the collaborators, interacting with the HoloLens to display more insightful data. With so many features available and limitless design templates, we will conduct a design study, performing interviews and collecting feedback on our design choices for the following user study.

4.2 Pilot Study

The original summer goal that we still intend to pursue eventually is producing a pilot study followed by a user study with HCWs during simulations. The pilot study will start with gathering consent and demographic forms, followed by

Fig. 4. Scene of healthcare workers performing simulations at Cornell Weill's Base Camp event

introducing the virtual environment to the team leader to familiarize them with the interactions. We will provide an overview of the seven multi-modals to gather feedback on what interactions, tasks, and visuals we should include to strengthen the environment modified after the design study. The simulation following could cover various medical events, but they always include a realistic manikin executing actions such as breathing, blinking, bleeding, and producing speech. Once the simulation is complete, a debrief will gather feedback from all members on how they perceived their collaboration, cognitive load, and teamwork. Further, we would get feedback from the team leader on their experience with the virtual application. We expect resourceful feedback on the design and flow of the virtual application through a thematic analysis of the debrief.

4.3 User Study

We intend to modify the virtual environment in preparation for the user study based on the feedback from the pilot study, which could include adjustments like new features or color changes. We intend to work with different HCWs at the same institution, starting with filling out consent and demographic forms. Following this, we will introduce the HMD to the team leader and allow them to become familiar with the chosen multi-modals that were recommended in the pilot study. Once the team leader is familiar with the application, the randomized simulation will take place where researchers will document critical moments that may indicate influences of collaboration, system usability, and cognitive load. The virtual environment the team leader will experience will have a modified hand menu from the pilot study that may include different, more, or fewer task options with more precise visual icons representing the task. Following the simulation, the simulation debriefs will occur, where HCWs will talk openly about their experiences and actions. The experiment debriefs will follow where we ask HCWs for their feedback on incorporating the HoloLens and if they felt it supported their collaboration with one another if it reduced their cognitive load, and if the team leader had problems or preferred using the device. Lastly, all participants would complete a questionnaire addressing their perceived cognitive load, collaboration, and system usability. After the experiment, we intend to perform a thematic analysis on the recorded debriefs and ANOVA tests on the questionnaires to compare to a group that did not use AR.

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