Towards Equitable CPR: An Interactive System for Female CPR Training

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ABSTRACT

Bystanders are less likely to perform prompt and effective CPR on women due to psychological barriers and lack of training on female physiology. Current CPR courses, often centered on male manikins, fail to address this gap. Broadening training to include female-specific scenarios could shorten response time and improve accuracy in emergency situations. In this paper, we introduce Equi CPR, an interactive system for female CPR training. This system includes a lightweight simulator for physical feedback and a MR application for guidance and visual feedback. We also conducted a preliminary user study of Equi CPR. The result shows that the system is effective and offers a positive user experience.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **Interaction design**.

KEYWORDS

Mixed reality, CPR, Gender differences, Interactive training, Haptic feedback

ACM Reference Format:
Yijun Zhao, Yang Zhou, Duola Jin, Tianshu Dong, Guanyun Wang, Fangtian Ying, Qihang Shen, and Jiacheng Cao. 2024. Towards Equitable CPR: An Interactive System for Female CPR Training. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '24), May 11–16, 2024, Honolulu, HI, USA*. ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3613905.3651092

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CHI EA '24, May 11–16, 2024, Honolulu, HI, USA

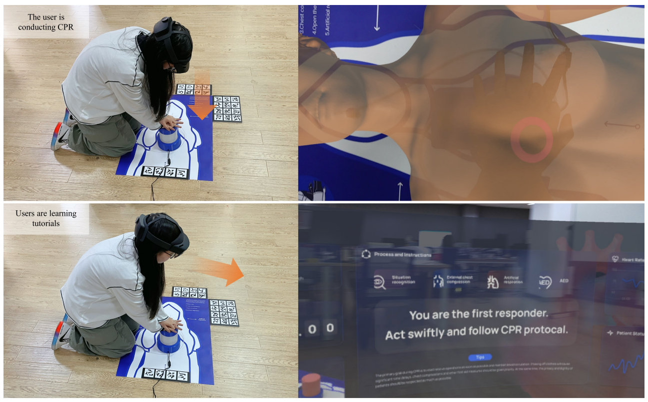
ACM ISBN 979-8-4007-0331-7/24/05
https://doi.org/10.1145/3613905.3651092

1 INTRODUCTION

Early cardiopulmonary resuscitation (CPR) is vital for treating sudden cardiac arrest (SCA) [17]. However, bystanders often hesitate to perform CPR on women due to embarrassment or concerns about physical contact and gender perspectives. This hesitation can lead to delayed treatment and higher mortality for women. Ahn et al. (2023) [1] underscored that this reluctance, along with physiological differences between genders, might result in improper CPR on women, decreasing their survival rates [7]. Additionally, women's bra and breast structure can also lead to insufficient compression or incorrect hand placement [3]. These factors highlight the need for CPR training that addresses gender-specific differences.

In the field of medical education, the interaction between humans and multi-sensor simulators employing technologies like mixed reality (MR) has garnered significant attention in human-computer interaction research [5]. Especially in the creation of a sense of presence, MR has significant advantages. However, existing CPR training systems often rely on male manikins and employ monotonous teaching and feedback methods, leading to incomplete training. Kramer et al. (2015) [8] highlighted this issue, noting that male-centric CPR simulators fail to convey the socio-cultural aspects of treating female patients, underscoring the need for immersive and realistic female-inclusive training systems. Therefore, we have decided to utilize MR to enhance immersion and interactivity, as well as to depict female physiological characteristics, aiming to better train bystanders to provide prompt and effective CPR to female patients.

In this paper, we introduce Equi CPR, an interactive system for female CPR training (Figure 1). This system consists of a lightweight simulator and a MR application. Supported by the lightweight simulator, Equi CPR offers a gender-inclusive training experience with a focus on aiding female patients, featuring interactive guidance, real-time feedback, and intuitive training for enhanced emergency response skills. To build this system, we conducted an education probe with experts and developed the prototype. To evaluate the effectiveness and user experience of Equi CPR, we conducted a preliminary user study. The result showed that both MR and 2D presentations effectively impart knowledge, with MR excelling in guiding physical actions, and users report a positive experience and increased confidence in responding to future emergencies.



(a) Scene of the use (b) User's view

Figure 1: (a) Scene of the use; (b) user's view.

2 LITERATURE REVIEW

2.1 Gender equity in the design of simulators for human-computer interaction research

In CPR education, the prevalent use of feedback-enabled manikins reveals a marked deficiency in diversity. Schwieters et al. (2023) [14] noted that most simulators on the market are based on the standard of males, which is insufficient for simulating women, especially when dealing with sensitive body areas. Liblik et al. (2023) [10] emphasized the need for simulators to better reflect the characteristics of different genders, calling for educators and manufacturers to improve current limitations.

In the field of human-computer interaction, researchers also have recognized the importance of addressing women's needs and promoting gender equality [6]. Navarro et al. (2020) [12] explored personalized stress management technologies for women, underlining the importance of customization. Søndergaard et al. (2020) [15] advocated for design approaches that address women's health, laying a theoretical basis for women-specific CPR device design. Dray et al. (2014) [4] stressed considering gender bias and neutrality in interactive technology design. Blewer et al. (2018) [2] examined gender disparities in CPR, emphasizing their consideration in developing women's CPR devices for effective female patient care. Future designs should focus on diversifying CPR simulators and fostering gender-equitable, women-friendly interactive technologies.

2.2 The presentation format of CPR training systems

CPR training systems can shorten users' response times and enhance their accuracy in real-life emergencies by creating a realistic sense of presence [11]. Enhancing the sense of presence is a positive learning approach that, when combined with self-directed learning strategies and reinforced behavioral control, theoretically increases the intention to perform CPR.

CPR training systems which allow learners to practice on their own can increase learning flexibility and offering a more immersive experience in handling emergency situations independently. Kwon et al. (2014) [9] highlighted the benefits of self-learning systems in CPR training, particularly when no instructor is present. They referred to "HeartiSense", a system that combines sensors and software with training manikins. This system improves learning with audiovisual feedback and provides practical assessments, enabling efficient and accurate learning independently.

CPR training system can also enhance the sense of presence by combining tangible components and creating realistic environments. Uhl et al. (2023) [16] proposed a mixed reality approach where trainees can use real tools and interact with physical human models in MR training scenarios, engaging with responsive virtual avatars. Ohshima et al. (2023) [13] designed an MR Basic Life Support (BLS) rescue training system, focusing on training basic life support skills, particularly including CPR and AED.

3 DESIGN PROCESS

To design Equi CPR, we initially conducted design probe sessions with experts. In this section, we describe the design process and the final design goals.

3.1 Design Exploration with Experts

We conducted a preliminary study with 2 experts (1F, 1M) from a local public hospital, who have more than 3 years of first aid experience and have conducted relevant education. Our design meetings, lasting about 60 minutes, involved presenting ideas, discussing the experts' past emergency and teaching experiences, and conducting semi-structured interviews about their perspectives on our CPR prototype. They concurred that specialized CPR education for females is vital and suggested: (1) Using female models in training for more realistic female patient scenarios; (2) Focusing on cultural sensitivity and privacy, particularly in the socio-cultural context of performing CPR on women; (3) Modify existing CPR equipment and training materials to enhance interactivity.

3.2 Design goals

Informed by our design probe sessions with experts and literature review, we set three key goals for an interactive system for female CPR training: (1) Increase the speed at which bystanders start CPR on patients, especially females, and decrease their hesitation due to gender issues; (2) Boost the survival rate of female patients post-CPR by including female-specific guidance in CPR training; (3) Add women's vital signs information to the educational content, thereby representing women's perspectives in the predominantly male field of medical education.

4 SYSTEM DESCRIPTION

Based on the design probe with experts, we developed the prototype, Equi CPR. Equi CPR is an interactive system for female CPR training (Figure 3), which aims to alleviate the psychological barriers bystanders face when performing CPR on females and enables trained bystanders to perform standardized CPR on both males and females. This training system consists of a lightweight simulator and an MR application (Figure 2). The features of the lightweight simulator and MR application are as follows: (1) Lightweight simulator: The simulator includes a physical feedback device and a training mat with AR tags. The physical feedback device comprise a chest compression part for measuring compression depth, force, and frequency and an artificial respiration part for measuring exhalation volume and frequency (Figure 4a). The training mat features human graphics with written procedural text instructions, and it allows for the replacement of backgrounds (Figure 4b). (2) MR Application: The application utilizes MR technology to create immersive scenarios, presenting 3D patients and guiding users in CPR practice through interactive dialogues. Users receive clear feedback on their actions. Additionally, the female CPR tutorial includes specific prompts aimed at reducing concerns among bystanders when performing CPR on women through pre-set methods.

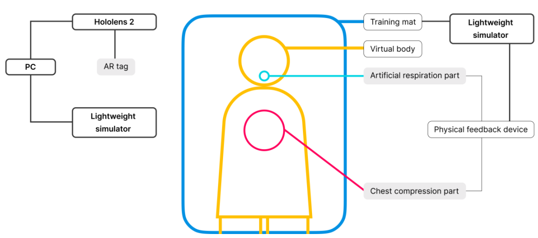


Figure 2: The hardware connections of Equi CPR.

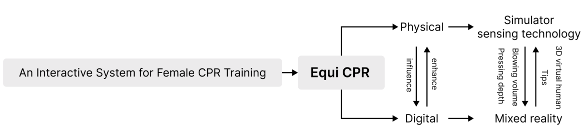


Figure 3: The conceptual framework of Equi CPR.

4.1 Simulator

Due to the user's primary focus on learning within the MR environment, the simulator has been designed to be lightweight. The simulator's main purpose is to simulate chest compressions and artificial respiration actions during CPR. As shown in Figure 4, the simulator features a range of components controlled by Arduino Uno, including an ultrasonic sensor, a resistive thin-film pressure sensor, a barometric pressure sensor, an OLED display screen, and a Wi-Fi communication module. It can accurately record the compression depth and frequency, as well as the volume of artificial respiration performed by the user during CPR, and transmit these data in real-time to a personal computer for analysis and recording. Currently, two versions of the training mat are provided in this research: female and male. These training mats aim to provide users with initial visual distinction between different gender.

4.2 MR application

We selected Microsoft's HoloLens 2 as the MR head-worn device to integrate into the female CPR assistance device, and the visual display within the glasses can be monitored remotely (Figure 5). By building the project in Unity using the universal windows platform (UWP) and utilizing plugins like the mixed reality toolkit (MRTK), we developed the project to include features such as gesture input, virtual world perception, and head tracking. This provides users with the ability to interact naturally with virtual content.

In terms of technology, we designed dedicated AR tags and implemented an image recognition module using the OpenCV library. This allows us to detect and locate AR tags in real-time video streams, ensuring that the human model appears in the specified position and is appropriately scaled to match the hardware device's position and size. Our hardware device is equipped with real-time data sensors that communicate with the Unity application. These sensors are responsible for capturing data related to interactions with the hardware device, such as compression depth and position. Through the input system of MRTK, we successfully synchronized this real-time data with corresponding elements in the virtual scene, achieving collaboration between the hardware and virtual components. Using MRTK's UI tools, we designed a user interaction interface that integrates real-time feedback and guidance into the center display of the HoloLens 2. This ensures that users can accurately understand the correct hand placement and compression depth required for CPR, thereby making the procedure more intuitive to perform.

In terms of interaction, the Equi CPR system aims to provide an efficient and intuitive set of tools for training and practical application of female CPR in MR (Figure 6). The system delivers educational content about the importance of CPR through virtual scenarios, text, and voice prompts. Users can see virtual human models and compression location cues through HoloLens 2, while the screen in front of them and voice provide instructions on CPR compression techniques and precautions. With built-in sensors and real-time data analysis, the Equi CPR system offers immediate feedback and monitoring capabilities. Users can receive real-time information about the quality of CPR, including key metrics like compression depth and frequency. This allows for timely adjustments to CPR procedures and training assessments.

In eliminating gender differences, our protocol includes specific guidelines for treating female patients. The system indicates if removing women's clothing is necessary and underscores the importance of prioritizing chest compressions and other first aid measures. For female, especially older, patients, the system advises locating the compression point at the sternum's lower third instead of the nipple midpoint. Despite anatomical differences, compression depth should be the same for both genders. The protocol clarifies that proper technique minimizes harm and encourages overcoming any hesitation in touching female breasts during CPR, emphasizing the urgency of life-saving actions in emergencies.

Through the above design, Equi CPR incorporates gender differences into its interactive content, providing an equal and effective guide for CPR. It encourages users to respond proactively in emergency situations, making users more sensitive and inclusive when using the system and ensuring respect for female patients.

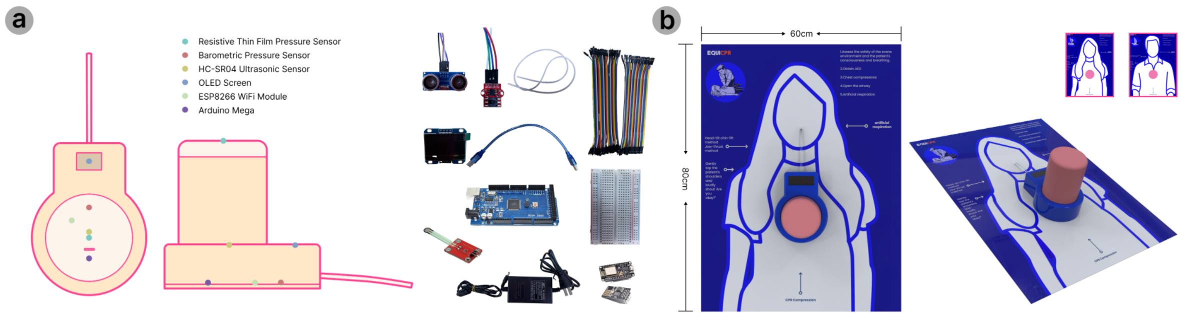


Figure 4: The simulator of Equi CPR: (a) sensor layout of simulator; (b) appearance of the simulator.

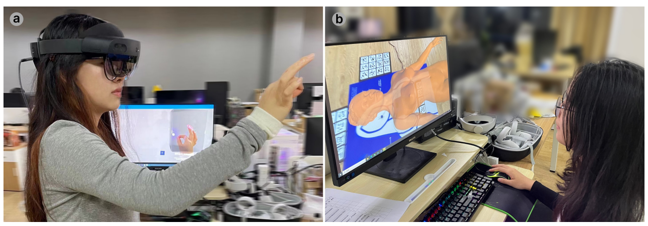


Figure 5: (a) The participant wore Hololens 2 for the interactive experiment; (b) the entire experiment process was monitored on a large screen.

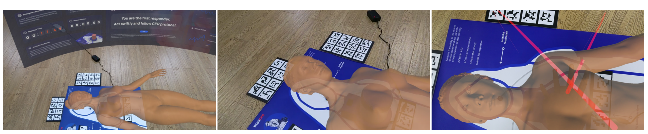


Figure 6: User's view in MR.

5 PRELIMINARY USER STUDY

In order to validate the effectiveness of Equi CPR in improving the quality of CPR education and considering the needs of women, while also assessing the user experience, we conducted a series of user tests. We recruited eighteen participants (9F, 9M, average age 24.5, SD = 0.40, SD = 0.36), ensuring a balanced gender ratio during the recruitment process, regardless of whether the participants had received prior education.

5.1 Procedure

Before the experiment began, we invited two expert doctors (1F, 1M) proficient in CPR to evaluate our hardware equipment compared to conventional manikins simulators. The two expert doctors confirmed that our hardware equipment provided appropriate compression force, timely and accurate feedback, and had the basic functionality of conventional manikins simulators.

To evaluate the effectiveness of the MR system, we split participants into three groups: Group A used the Equi CPR system with MR (Hololens 2), Group B with a 2D display (TV), and Group C used a basic simulator. We used custom hardware with the same sensors to avoid biases. All participants watched a CPR video before training. Post-training, we tested their CPR skill, focusing on chest compressions and artificial respiration, and their CPR knowledge, including basic concepts, scenarios, and female-specific questions.

(a) Equi CPR (b) 2D CPR (c) Only hardware CPR

Figure 7: Control group experiment.

To assess user experience, participants were subjected to semi-structured interviews focusing on three main themes after their training, primarily targeting Group A: (1)Their relationship with Equi CPR; (2)Their opinions on the future development of Equi CPR; (3)The differences between traditional learning methods and Equi CPR.

5.2 Results

In terms of effectiveness, statistically significant difference existed among the three groups regarding the level of knowledge (Kruskal-Wallis H test, p=0.002) and skill (Kruskal-Wallis H test, p=0.004), as shown in Table 1. Using the Mann-Whitney U Test, the knowledge test showed significant differences between Groups A and C (p = 0.004), and B and C (p = 0.004), but not A and B (p = 0.082). In the skill tests, significant differences were noted between Groups A and B (p = 0.012), and A and C (p = 0.003), with no significant difference between B and C (p = 0.243). The results suggest that both MR technology and 2D screens as educational tools in Equi CPR positively impact theoretical knowledge, particularly in female CPR. It is noteworthy that MR technology showed a distinct advantage in teaching CPR actions, especially in improving the accuracy of chest compression location, a critical aspect of female CPR.

In terms of user experience, participants in Group A generally shared four common viewpoints during the semi-structured interviews: (1) The system provides timely feedback and is easy to correct; (2) It feels engaging and prevents training from being boring; (3) They learned a lot about CPR specific to women; (4) They

Table 1: The median scores of CPR knowledge and skill level tests for each group.

Group	Knowledge test(max: 100)	Skill test(max: 10)
A	77.50	7.50
B	70.00	6.00
C	45.00	5.00

hope for more learning modes. These viewpoints further supplement the effectiveness of the system and provide valuable insights for our future research endeavors.

6 LIMITATIONS AND FUTURE WORK

This study has some limitations, primarily in two aspects. First, we engaged with only two CPR education experts due to time and geographical limits, which may have restricted our perspective. Second, the short duration of the experiment may have limited our understanding of the long-term effects of Equi CPR education on memory retention.

About future work, Equi CPR is committed to simulating diverse emergency scenarios for healthcare professionals' training, focusing on varied symptoms, ages, genders, and body types.Additionally, we plan to integrate Unity-based design with the newly launched Vision Pro for MR technology, enhancing the diversity and immersion of Equi CPR's interactive content.

7 CONCLUSION

In this paper, we introduced Equi CPR, an interactive system for female CPR training. Equi CPR utilizes a lightweight simulator to provide physical feedback, a MR application to visualize virtual human models, gender-specific customized tutorials, and various quantified visual feedback to assist users in self-learning CPR and enhance the sense of realism. Our user studies have demonstrated the effectiveness of Equi CPR in improving CPR training quality and addressing the needs of women, with positive user experiences. We are confident that Equi CPR will enhance the inclusivity and depth of medical education in the future by providing increasingly diverse and immersive interactive content.

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