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Augmented Reality enhanced device usage training tool for in-home health-self-monitoring by pregnant women

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Abstract. Virtual care comprising virtual visits and monitoring via audio or video has the potential to reduce access barriers to care and has been successfully implemented in prenatal care. It reduces the frequency of in-person visits and increases self-care skills. However, the knowledge and competence in handling monitoring equipment at home directly influences satisfaction and engagement with the system and the quality of the information provided to healthcare professionals. Therefore, providing ad-hoc training to end-users would help develop confidence in using devices at home correctly. This paper proposes an augmented reality (AR) application to guide and train pregnant women to use monitoring devices. The aim is to instruct pregnant women to use the monitoring devices and follow the video guidelines for handling them correctly. It validates pregnant women's encouragement and ability to self-care for their pregnancy.

Introduction

Nowadays, telehealth or virtual care interventions are gaining popularity in different healthcare sectors, including pregnancy (Nelson & Holschuh, 2021). Telehealth or virtual care comprises synchronous virtual visits via video or audio incorporating bi-directional communication/consultation between healthcare professionals and patients or asynchronous communication, remote patient monitoring, data transmission, and data sharing (Ghimire, Martinez, et al., 2022). Owing to the potential complications and being highly vulnerable to spreading diseases and pandemics, pregnant populations were stringently advised to follow healthcare measures during the COVID-19 pandemic, highlighting the relevance of virtual prenatal care (Almuslim & AlDossary, 2022). Virtual prenatal care includes remote monitoring of pregnant women, where pregnant women monitor their health status themselves by using different medical equipment such as blood pressure sensors, devices, etc. (Ghimire, Martine, et al., 2022). It has the potential to reduce access barriers to care, and increase self-care skills, allowing a reduction in the frequency of in-person visits. However, it necessitates the qualification of pregnant women to handle such devices.

Moreover, it is crucial to guide and qualify medical users in adapting to handle medical devices to achieve safer, more efficient, and effective outcomes (Ribeiro et al., 2019). With the advancement in biotechnology, wearables, and other medical and healthcare sensors and actuators, the need for medical users to be well-qualified to use such devices correctly and efficiently has increased. It often requires specialized engineers to handle more complex and specialized medical devices and their functions (Ribeiro et al., 2019). With virtual prenatal care, pregnant women, as central users, need the training and skills to handle those monitoring devices that are essentially for the routine assessment of the health status in virtual prenatal care. However, not every pregnant woman has all the skills to operate all required devices and their functionalities. Most of the pregnant women from regional areas or low-income groups generally lack technical skills and have no health literacy or are illiterate, thus, it is very challenging for those population to handle the devices, take measurements accurately and interpret those measured data. According to the studies on pregnant women's experiences and satisfaction with virtual prenatal care, discomfort in using devices and technical incompetence in handling device by pregnant women themselves was the significant barrier to participating and continuing virtual care at home (Ghimire, Martinez, et al., 2022). Thus, the usability of virtual prenatal care that includes self-monitoring of the health status of pregnant women themselves demands a state where the users can perform the monitoring more efficiently and effectively while enjoying the experience. The emerging Augmented Reality (AR) technology that overlaps virtual objects/ information on top of the real environment (Carmigniani & Furht, 2011) is a promising option explored in this study with the aim to instruct or guide the device users by superimposing device-relevant information on top of the device itself.

This paper proposes an application for mobile devices using AR to improve the usability of monitoring devices for pregnant women at home. With the support of AR, pregnant women can access information and guidance about the use and operations of their devices through several informational images and videos. It seeks to provide numerous information on the initialization of the device and measurement procedures, characteristics, risk factors, and interactive contents related to the device and measured values. The overall architecture of the system is illustrated in Figure 1. General monitoring devices used in routine prenatal visits, such as blood pressure monitoring device, oximeter, and temperature sensor are integrated into the presented prototype of this application.

Related Works

AR has been implemented in various fields, including medicine, in several ways: educating patients, students or medical staffs, training or procedural plannings, visualization aids in practices, remote collaboration, and telemedicine (Arpaia et al., 2021; Chamberlain et al., 2016; Cox et al., 2019; Munzer et al., 2019). Most AR applications as educational tools are employed for medical staff, students, or patients to educate them in specific disease or area of disease (Nifakos et al., 2014; Ribeiro et al., 2019). No studies have been found that employs AR for training patients to use medical devices themselves at their own home in remote patient monitoring. Similarly, numerous works have been done for prenatal care and virtual prenatal care, including remote monitoring of pregnant women (Ghimire, Martinez, et al., 2022); however, none employed AR for medical device use. Also, there exists an augmented reality tool for remote assistance to remotely guide people in factories or in need of assistance without being there, however, it is less practical for the rural regions where there is a lack of healthcare providers, and providing remote assistance has time constraints. Thus, we propose a system that supports pregnant women in handling the devices on their own, reducing the burden on healthcare providers.

Methodology

The proposed application of AR technology is a learning tool to provide information and guidance for the operation of specific healthcare self-monitoring devices is validated experimentally with a corresponding proof-of-concept prototype. The overall architecture of the system is illustrated in Figure 1. It contains three elements, which interact with each other, the users (pregnant woman in this specific study case), the user device (i.e., a mobile phone), and the real-world entity (i.e., the included monitoring devices). The prototype is developed following a rapid application development (RAD) approach, which consists of three main phases: requirements and problem definition, prototype design and development, and testing in terms of functionality and usability (Abd Ghadas et al., 2015; Kirpitsas & Pachidis, 2022; Martin, 1991). It is a software development process based on prototyping, where more priority is given to the development task than on the planning. It aims to develop a system in a short period of time. This methodology has been selected for faster development and implementation of the application, as it aims much faster development and implementation than the other methodology by collaborative participation of users in prototyping (Abd Ghadas et al., 2015; Kirpitsas & Pachidis, 2022; Martin, 1991).

Requirements and problem definition

This phase aims to identify problems, investigate existing works in the related fields and discover user requirements and gaps within them. Thus, a literature study was conducted to explore the information regarding approaches in practice for in-home monitoring systems for pregnant women and to investigate the used technologies, especially for supporting pregnant women in using monitoring devices correctly. The literature study on an in-home monitoring system for pregnant women to explore the technology used and its effectiveness and barriers indicated that training and usage support for handling monitoring devices is a prerequisite for the effective usage of an in-home monitoring system (Ghimire, Martinez, et al., 2022). A total of 23 studies were selected and analyzed in order to investigate the shortcomings and open issues of in-home monitoring systems for pregnant women. The study's findings demonstrated that pregnant women were more hesitant to use the whole monitoring solution due to a lack of skills and knowledge for correctly handling the monitoring devices (Ghimire, Martinez, et al., 2022). Thus, to address this issue, another literature study was conducted to explore the feasibility of technologies that have the potential to improve the effectiveness of training tools (Ahmad et al., 2021; Arpaia et al., 2021; Chamberlain et al., 2016; Cox et al., 2019; Ginting et al., 2021; Munzer et al., 2019; Nifakos et al., 2014; Nurlaily et al., 2021; Ribeiro et al., 2019). The preliminary search and analysis were performed in Google Scholar and Scopus to avoid duplication of the work, identify relevant articles addressing the problem in the first literature study (Ghimire, Martinez, et al., 2022), and ensure the availability of enough articles for the analysis. The literature study also gathered data from similar research fields to find useful technology that fits with problem statement. From this literature study, it was found that AR technology has been used as a training tool for educational and training purposes in a wide range of medical fields. However, no studies were done in the field of in-home monitoring systems, especially targeting the patient to make them handle the monitoring devices themselves.

Thus, the findings from the study revealed that the requirement or the target problem is the (potential) lack of skills and competencies of pregnant women in handling pregnancy monitoring devices themselves as part of an in-home pregnancy monitoring system. Since incompetence or lack of knowledge in handling equipment can result in reduced engagement to the system and likelihood of discontinuing the system, it directly impacts the overall success and efficiency of the monitoring system and its sustainability.

Prototype Design and Development

In this phase, the prototype development of an augmented training tool for handling monitoring devices for pregnant women was conducted, for which augmented reality technology was utilized. This augmented reality application was developed using Unity (Unity Engine 2021.3.4f1) (Unity 3D) and the AR foundation for Android smartphones. The application allows pregnant women to easily access device information and measurement guidelines on scanning the device with the application on their smartphone. The prototype supports two different medical monitoring devices for pregnant women, a blood pressure monitoring device and a pulse oximeter, which are generally used in routine prenatal visits. The prototype testing and evaluation were done using a Samsung phone (Samsung Galaxy A53, android OS), where two monitoring devices, an A&D UA-651BLE blood pressure monitoring device and Nonin Onyx 9560 Fingertip pulse oximeter, were used as a test device.

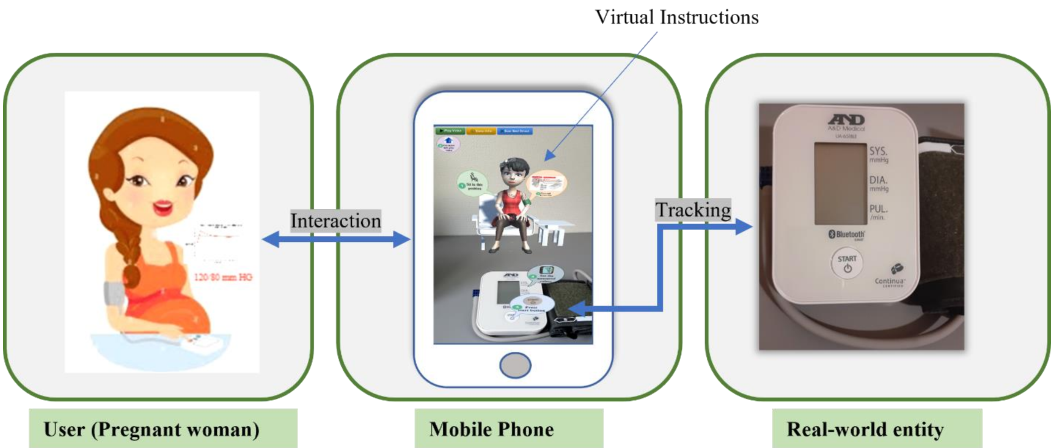

Figure 1. Augmented reality system architecture of the proposed application.

Testing: Functionality and usability

In this phase, testing and evaluation of the application were performed. Specifically, the functionality and usability of the application were assessed to find if the users find its functionality easy, usable, and appropriate. The testing was based on lab usability testing following a qualitative approach. For this, twenty potential users were involved, who had no previous experience using augmented reality application and were divided into different groups. The lab usability test was carried out in the usability laboratory at the University of Agder Grimstad/Norway, where the test users were asked to complete specific tasks (as listed in Table 2) using the application prototype. One group of participants was divided into “test user” and “observer” and allocated to corresponding rooms. Two rooms divided by a one-directional mirrored window were allocated for the test, where the test users, together with the test instructor, stayed in a test room, while the observer stayed in the controller room observing the test through the mirrored window. All the test users were asked to use the app with different medical devices and to test and evaluate the overall functionality. The focus of the test and evaluation was the usability of the prototype application and the efficiency to provide information to the test users that allowed them to achieve their goal in learning about the device operation and to collect feedback and suggestions on the overall system. Also, this approach allowed us to collect qualitative data about the users' attitudes and reactions and to provide instant feedback on their questions in real-time.

Table I. Areas asked to the participants for testing and evaluation of the App

SN	Title
1.	Usefulness of the instructions provided in the app
2.	Usefulness of the app
3.	Clarity and alignment of the virtual and real image in the app
4.	Overall functionality and user interface in the app
5.	Easy to use
6.	Improvement ideas

Results and discussion

Description of the developed prototype

The prototype included training and usage information for two monitoring devices, a blood pressure measurement device and a pulse oximeter. However, more medical devices and their training and handling information can be uploaded to the system. The overall functionality of the application is as described subsequently. When the pregnant woman opens the training and usage support app on her mobile phone to scan a monitoring device, e.g., a blood pressure measurement device, the virtual image of a woman appears on the mobile phone screen, presenting instructions about handling the monitoring device. In addition to the augmented instructions, three buttons appear on the mobile screen, allowing pregnant women to access further information, as shown in Figure 2. The instructions for handling the device give basic step-by-step pop-up instructions on where and how the device should be attached to the pregnant woman's body and how the measurement is done. If the information in the instructions is insufficient to learn to handle the measurement device, a pregnant woman can use the support buttons on the mobile screen. The *play video* button allows pregnant women to watch a video that gives detailed instructions on using the particular device. The video can also be played in full-screen mode. The second button provides information about the follow-up on the measured values. It gives information about the measured values and associated risks, especially data interpretation. Once the first and second buttons are clicked to watch a video or to get information on the interpretation of the measured values, the app stops tracking the device so that the pregnant woman can watch the instructional video without focusing the camera on the monitoring device and use the device for measurement. Also, she can see the information about potential risks associated with the measured values. The third button allows the scanning process for the next monitoring device by starting to track the device.

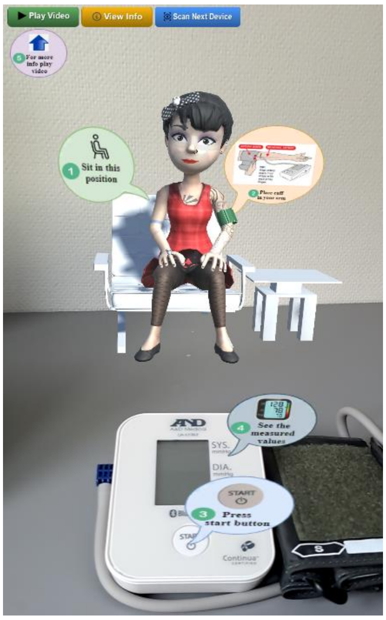

Figure 2.The app screen with instructions after scanning the monitoring device.

Results of testing and evaluation

The prototype was evaluated by nursing students as representative general pregnant women to evaluate how the system can guide pregnant women in using the application. The test and evaluation addressed the functionality and usability of the application and involved 20 nursing students (4 groups of 5 students). Among these 20 students three were male and 17 were female nurses. It was found that none of them were familiar with AR technology or AR applications. The participants were asked about the perceived usefulness of the provided instructions and usability of the app. The overall responses obtained from the test users are shown in Table 3. All participants (100%) expressed that the app was useful and relevant for pregnant women to use as a training tool. They showed their acceptance of the application. They expressed the application's ability to display the usage instructions for monitoring devices just by scanning them, without any need to type device names or to search through the application/internet or any requirement to have any training to use the application and enter the login information, as an insightful advantage. It is an easy and fast process. In addition to the provision of basic instructions, the possibility to access a more detailed instruction guide via video and other relevant information about the monitoring device was mentioned as the other positive aspect of the app. However, using the AR application as a training tool to support the measuring process by seeing usage instructions in the application was difficult due to the movement of the virtual image and the included instructions with the real device, which they (25% of them) considered a negative aspect in terms of usability.

They expressed that the app could be more useful if the virtual image and the instructions could be viewed constantly in a fixed position without the need to focus the app on the real monitoring device continuously. On the other hand, evaluation regarding the intuitiveness of functionality and user interface of the application was not satisfactory. Half of the test users were satisfied with the functionality and user interface, while the other half were not. All the users (100%) expressed concern about the text size of the instructions displayed on the mobile screen, where the virtual image could be magnified while the instructions could not. Some suggested that animated instructions could be more efficient than the tested approach of augmented instructions.

Table II. AR mobile application usability testing (n=20)

Title	Positive Response	Negative Response
Usefulness of the app	20 (100%)	0
Clarity of the instructions provided in the app	0	20 (100%)
Clarity and alignment of the virtual and real image in the app	15 (75%)	5(25%)
Easy to use	15 (75%)	5 (25%)
Overall functionality and user interface in the app	10 (50%)	10 (50%)

Some of the instant feedbacks provided by the test users after testing the application is listed below:

User 1:

"The application is very interesting, simply by scanning the device we can visualize the instructions."

User 2:

"The instructions are not visible and since the instructions are also not stable and moving, how could a pregnant woman use the monitoring device by having the mobile phone in one hand? This might be less practical."

User 3:

"This application could be more useful specially for other devices that are more complicated to handle."

User 4:

"Difficult to scan the device, the alignment of the virtual image is sometimes moving."

Considering the improvement suggestions by the users, the prototype has been iteratively developed further. The virtual image's position and instructions can now be fixed anywhere by the user by tapping in the desired location on the mobile screen. Also, the instructional text is now visible and can be magnified. Besides, implementing animated instructions is a promising approach to further improve the usage support for monitoring devices, and will be considered in future work.

Conclusion

AR application in handling monitoring devices for pregnant women in an in-home monitoring system was successfully designed and developed throughout several phases. The users' responses and suggestions show that AR can be easily used in a virtual care environment to support patients at home without healthcare professionals, providing more efficient healthcare practices for healthcare professionals. In future work, it is worthwhile to assess users' needs and requirements by directly involving users in system design and development. For this, human-centered methodologies such as focus group discussions, interviews, and questionnaire surveys will be considered.

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