

System Usability and Technology Acceptance of a Geriatric Embodied Virtual Human Simulation in Augmented Reality

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Figure 1: This figure illustrates the entire setup of our study. Starting from the left, the human controller is hidden from the interaction space behind the room divider. In the middle, the virtual human stands by the bed looking at the participant. At the right, a participant is interacting with the virtual human.

ABSTRACT

With the rise of the aging population, the demand of care increases yet the turnover rate of caregivers for geriatric patients has increased over the past few decades. While many factors contribute to the caregivers' turnover rate, inadequate training and lack of communication skills and relationship-building skills are vital issues. Technology can help in providing training for soft skills. Embodied Virtual Human (VH) assistants and Augmented Reality (AR) can be a key method to train caregivers and to improve their experience in interacting with older adults, and their perception of the interaction. We designed and developed an immersive simulation in AR where caregivers interact with an embodied VH in two different conditions, i.e., first with an unaware VH and then with a VH having simulated awareness achieved through human-in-the-loop. We conducted a study with caregivers of older adults to evaluate the usability and technology acceptance of our system. The findings suggest that the majority of the participants found the system

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acceptable, and rated the system as user-friendly and easy to use.

Index Terms: System usability, technology acceptance, virtual human, augmented reality, AR, geriatric, older adults, simulation, aware virtual human, virtual assistant, geriatric patient.

1 INTRODUCTION

High turnover rates in geriatric care, exceeding 33% and reaching up to 70% in skilled nursing facilities, present a significant challenge in the face of increasing demand for caregivers; an estimated 67 million people over age 60 currently requiring care with an additional 65 million Americans reaching 65 in the next

two decades [16]. Two common causes of turnover rates are lack of communication skills [21] and inadequate training among caregivers [53]. It is reasonable to suggest that enhancing existing caregiver training programs and incorporating modules to develop communication skills could serve as a unified solution to these two issues. Nursing colleges frequently employ a diverse array of simulation tech-

niques for caregiver training, particularly for those working with geriatric patients: high-fidelity mannequins (computer-controlled full-body replicas), low-fidelity mannequins (simpler models used for basic care), role-playing exercises (students taking on roles of patients and caregivers for exercising communication and decisionmaking skills) [44]. The adoption of immersive technology such as Augmented Reality (AR) and Virtual Reality (VR), which offer interactive experiences in a secure and controlled setting, is gaining popularity in medical and healthcare education [29]. Moreover, embodied virtual patients are being used in fields like psychiatry and geriatrics that offer the opportunity to engage in faceto-face human-like interactions providing a framework for training clinician-patient communication skills [14]. In addition to communication training, virtual patients are used to simulate various clinical scenarios, allowing students to interact with patients and practice their socio-cultural background assessment skills [61].

In the growing field of immersive embodied virtual patients, ongoing research efforts are focusing on the development of communication skills, fostering relationship-building abilities, and improving quality of care [14, 22, 32]. In this paper, we present a novel simulation framework of an embodied VH giving the impression of having awareness in an immersive AR environment to train caregivers of geriatric patients in communication and relationshipbuilding skills. We designed and developed the simulation software and content, conducted a study with professional caregivers, and evaluated the system usability and technology acceptability of our system.

2 RELATED WORK

Virtual assistants, powered by Artificial Intelligence (AI), are finding applications across a wide range of fields including conversational voice assistants such as Amazon Alexa, Apple Siri, and Google Assistant for everyday use, commercial virtual assistants for customer support, virtual healthcare assistants, and many more [50, 42]. In particular, the healthcare sector is witnessing a rapid expansion in the use of assistive technologies like conversational voice-only agents [37], disembodied virtual assistants [31], service robots [25], and sensor-based monitoring systems [7] due to the advancements in ubiquitous computing and aims to support a broad user base comprising patients and healthcare providers [28, 39]. Newer generations of immersive virtual assistants are being deployed in the healthcare sector compared to old virtual assistants that were displayed on 2D displays or projectors [38]. More specifically, these new generations of virtual assistants are evolving into embodied virtual humanoid assistants [24]. Embodied virtual assistants outperformed voice-only interactions in terms of social presence and engagement [33]; additionally, the quality of appearance of the embodied virtual assistants positively affects the user experience [24]. This could be an indicating factor to the usability and acceptability of embodied immersive virtual assistants among users.

In the exploration of embodied agents, an awareness of both the virtual and physical space around the agent was developed, with attention given to user's gestures, body language, gaze, and verbal communication [41]. Newer generations of AR virtual humans with environmental awareness demonstrated the ability to enhance social interaction among users [34, 6, 5]. A negative

impact was revealed about virtual reality on body awareness, mediated by the feeling of being embodied in and changed by the avatar [19]. The attributes of communicative interaction using embodied minimal avatars in room-scale virtual reality present the potential for same-time, sameplace settings [26].

AR based systems are being used increasingly, more specifically, in the field of health and medicine [27]. To support dementia patients and their caregivers, a virtual agent named Anne was designed with the intention of fostering independent living at home [18]. The usability and acceptability of Anne were evaluated in a home environment setting, revealing significant engagement from older users and identifying speech recognition issues that affected the intention to use [56]. An AR system was proposed to facilitate effective training and enhance care communication skills, demonstrating its effectiveness in improving caregivers' physical skills and empathy [45]. The feasibility and acceptability of an AR prototype for Basic Life Support training were assessed, with positive feedback on its ease of use and interaction through voice, gaze, and gesture [30]. A comparison made between virtual-based medical education and the lecture-based method in teaching start triage lessons to emergency medical students revealed that while VR can effectively improve knowledge, it was not more effective than traditional educational methods [10].

Disembodied virtual assistants have been used in geriatric care for various purposes such as providing daily assistance, facilitating interaction with older adults, behavior change and self-care [64, 11, 9]. Disembodied immersive virtual assistants, for instance, cARe, an AR simulation, assist older individuals with cognitive decline in their routine tasks, thereby enhancing their independence in an enjoyable manner [63]. Older individuals have expressed their acceptance of virtual simulations, such as finding AR-based virtual coaches for balance training both encouraging and stimulating [43]. Embodied Virtual Human (VH) based simulation is a valuable tool as it allows clinical teams and researchers to study and model the verbal and non-verbal behaviors of clinicians or students, which can be achieved by manipulating the cognitive behavior and the visual appearance of the VH [14]. A controlled experiment allows VHs to become powerful tools for studying the social interactions between clinician and patient, however, research in the fields of psychiatry and geriatrics has primarily focused on using the VH to simulate specific clinical encounters or on evaluating the simulation tool itself, considering aspects such as feasibility, credibility, and usability [14]. In the domains of psychiatry and geriatrics, the primary application of VHs is for specific clinical simulations or tool evaluations. Among the available VH simulation tools, some lack the capacity for human-like dialogues [13, 48, 55, 15, 51, 52], while others provide immersive experiences with life-sized VHs and natural language interaction [46, 47, 20, 49, 54]. However, some tools, particularly those based on web interfaces or pre-recorded videos, may lack a sense of realism.

The existing literature indicates numerous endeavors to employ realistic embodied virtual humans in the domain of older patient care, to enhance users' communication skills and interaction quality [24, 14]. As far as we are aware, no attempts have been made to integrate environmental awareness into VHs in the context of geriatric patient care. We propose a novel immersive AR simulation framework that incorporates the element of simulated conversation and environment awareness into the VH. Our aim is to create a simulation that is both usable and acceptable to the users while having the potential of simultaneously enhancing interaction and user experience. In the context of this paper and research study, the user is a caregiver of older adults.

3 SYSTEM DESIGN

We developed a comprehensive framework in the Unity game engine [59] that includes four primary elements: a 3D model, control of VH responses, integration of VH emotions and gestures, and VH's awareness. Users are presented with an AR interface featuring a 3D model (VH) of an old woman through the Hololens 2 head-mounted display. The VH is capable of engaging in natural conversations, exhibiting emotions and body gestures, and creating an illusion of having awareness of her surroundings. We employed the Wizard of Oz strategy to control the VH's responses; during interactions, a human controller selects suitable responses from a preset pool of VH responses. The VH exhibits awareness by controlling IoT devices, recognizing users by name, commenting on users' attire colors, and remembering previous conversations. These components include multiple subcategories that were combined to construct the simulation as described below.

3.1 3D Model and Animations

We used Autodesk Maya [8] to 3D model and texture a realistic old woman, and to rig the human body and facial expressions. The 3D model allows us to incorporate additional elements such as eyeglasses and hearing aids, alongside custom-designed clothing needed to portray an older character. The inception of this project was driven by the objective to design and develop a highly realistic 3D model of an old female character, capable of showing animations and facial expressions that echo the subtle nuances of real human gestures and movements (see Figure 2). The process was informed by high-quality references, including 3D scanned data and digital assets from platforms such as 3dsk [2] and Turbosquid [58], ensuring anatomical accuracy and authenticity in skin texture portrayal.



Figure 2: The left column represents different body gestures made by the 3D model. The middle and right columns represent the front and side view, respectively, of the 3D model.

The character was created with a focus on human anatomy that matches the aging process' effects on skin and form. The 3D model is composed of 778,092 vertices, 1,496,271 edges, and 719,428 faces, with a mesh topology that is designed for real-time animation. Texturing played a pivotal role in augmenting the realism of the character. We used Adobe Photoshop to create lifelike skin textures, that we mapped to the UV layouts of the model for realistic appearance. The texture resolutions are 2048x2048 pixels, balancing detail and performance.

The rigging of the skeletal structure is comprising 67 joints to allow for a wide range of motion and flexibility. The rigging of facial expressions used blend shapes to model facial expressions simulating a range of emotions such as happiness, sadness, and surprise. Visemes [1] and Phoneme also used blend shapes to simulate lip movement during speech. Advanced techniques such as Dual Quaternion Skinning and Weighted Vertex Normals were utilized to ensure smooth and natural deformation of the mesh during animations. The rig includes custom controls for nuanced facial animations, utilizing blend shapes for visemes and expressive gestures. Custom clothing was designed to reflect the style and practicality suited to the older adult demographic, incorporating fabrics and patterns that align with the character's personality and lifestyle. This involves the use of cloth simulation tools within Maya to ensure realistic fabric dynamics and interactions with the character's movements.

3.2 VH Response Control

We adopted a human-in-the-loop strategy to manage the VH's responses. A human controller, operating behind the scenes, listens to the dialogue between the user and the VH and selects responses from a predefined pool. The controller is equipped with a Graphical User Interface (GUI), displaying buttons that each correspond to a pre-set response for the VH. These responses are systematically organized in a spreadsheet. Upon clicking a button, the corresponding data from the spreadsheet is retrieved and transmitted to the VH, which then responds with the chosen response and relevant emotions and body gestures. The components of the response control system are depicted in Figure 3.

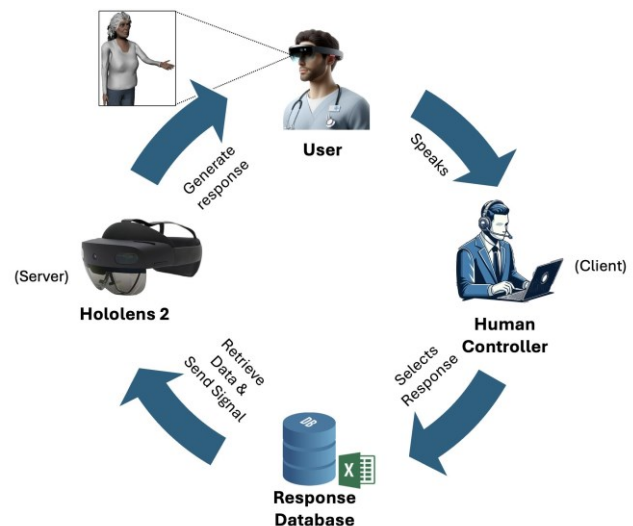


Figure 3: Workflow and data transmission flow of the simulation.

3.2.1 Graphical User Interface (GUI)

The VH is controlled via a series of buttons that initiate speech, animations, and emotional expressions. These buttons are distributed across a primary panel, a secondary panel, and an assortment of button panels. The primary panel serves to open and close a category of buttons, termed a button panel. For instance, buttons that instigate speech pertaining to the "Family" category would be assembled in the "Family" button panel. Users (e.g., a human controller) can access the "Family" panel, located on the lower right, by selecting the "Family" button in the primary

panel. Subsequently, the associated buttons, such as “Where is my son?”, become visible (see Figure 4).

The secondary panel, also referred to as the “Common” panel, was designed to provide users with rapid access to frequently utilized speech, including phrases such as “Hello” and “I am Rose Johnson”. The ability to swiftly navigate between panels is crucial for generating convincing responses. The primary panel buttons facilitate transitions between button panels without necessitating the closure of the preceding panel. The button system is written using CSharp. Upon initiation of the simulation, the button manager parses an Excel file containing button data. This data includes columns for “button name”, “audio file”, “category/panel”, and “emote”.

The manager constructs panels for all button categories. Each row of the Excel file is preserved as a button object, which is subsequently utilized to instantiate a button. The category of the button is verified, and it is then appended to the appropriate panel. It is assigned an audio clip to play and an emotion to display on the model. Upon clicking the button, a function is invoked on the model’s animator component and the SALSA LipSync package [57].

The most challenging part of the button manager was optimizing the spacing between buttons to ensure they fit in the smallest possible space on the screen, thereby enhancing the efficiency of button search response time. A couple of layout components were employed to establish rows of buttons on each panel, facilitating the dynamic spacing of buttons with varying lengths of button labels.

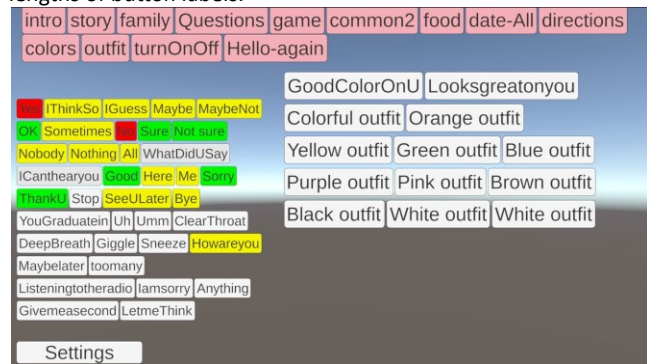


Figure 4: Graphical user interface of the response buttons. The top pink panel indicate separate categories of responses/buttons. The lower left set of colorful buttons belong to the quick response group. The group of white buttons on the right are the responses from the chosen category of the top panel.

3.2.2 Response Control Database

We have developed a semi-automated database system, hosted locally in Unity, to handle the data related to the VH’s responses, facial expressions, and body gestures. A spreadsheet holds all the essential details about a specific response, such as the response text, the button’s name that represents the response, the panel to which the button is assigned, the color code of the button, the name of the audio clip for the text, the link to the audio clip, and much more. The GUI of the button manager can be dynamically rearranged by updating the spreadsheet’s information. The addition and removal of buttons, audio clips, and other elements can also be accomplished in the same manner. When the human controller clicks on a button, the relevant information is transmitted to the VH, enabling the continuation of the conversation.

3.2.3 Data Transmission

We established bidirectional real-time communication using the Transmission Control Protocol (TCP) and socket programming. This setup facilitates the exchange of information between the VH and the human controller in real-time. The communication we refer to here is the network interaction between the computer (used by the controller) and the Hololens 2 device (VH). We adhered to a server-client protocol where the Hololens acted as the server and the computer as the client. The study commenced with the establishment of a connection between the server and the client, initiated by a port connection request from the client to the server. When the VH needs to respond to the user, the human controller clicks on a specific button on the GUI; this action retrieves the necessary information from the spreadsheet and transmits it to the VH via the communication channel. Upon receipt of the signal from the human controller, the VH initiates the corresponding audio speech, facial expressions, and body gestures.

3.3 VH Emotions and Facial Expressions: A Custom Unity Plugin for Facial Expression and Emotion Generation

We employed the SALSA LipSync package [57] in Unity to develop our custom plugin that dynamically generates and triggers facial expressions and emotions. Facial expressions refer to movements such as eyebrow-raising, lip movement, squinting. Emotions refer to feelings such as happiness, anger, sadness, worry, etc. Our plugin adjusts two distinct components of SALSA. The SALSA component and the emoteR component in SALSA are responsible for controlling these facial expressions and emotions.

These components utilize an automated process to identify and trigger facial expressions and emotions using blendshapes when an audio clip is attached and played. However, manual setup of the components with the blendshapes is required, for instance—setting up the trigger time, duration, blendshape names, randomizing expressions, attaching an audio file, etc. With our plugin, all the settings in the SALSA and emoteR components are automatically configured, and facial expressions and emotions are triggered with the corresponding audio clip when the VH receives a signal from the human controller.

3.4 Simulating VH Awareness

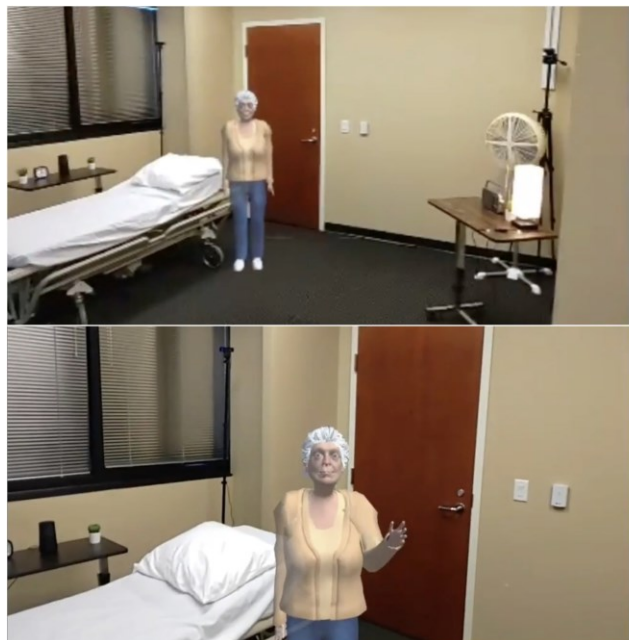


Figure 5: The top figure shows the users' point of view and the bottom one shows the VH pointing towards the lamp while asking the users to switch it off.

We integrated the awareness feature into the VH using three distinct techniques: managing IoT devices, recognizing users by their names, and discerning the colors of users' attire relating to previous conversations. The VH demonstrates the ability to switch devices (i.e., a lamp and a radio) on and off using a remote control, with the human controller performing the actual task on behalf of the VH. We gathered the participants' names during the recruitment stage to incorporate the "addressing users by their names and identifying the colors of their attire" features. We programmed the VH with these names and a predetermined set of colors to infuse the VH with memory and awareness capabilities.

4 EXPERIMENTAL STUDY

We conducted an experiment with two interaction scenarios involving the same participant cohort. The system emulated dialogues between an older adult (the VH) and a caregiver, aiming to demonstrate the VH's ability to recall prior conversations. The first session was an introductory conversation with an unaware VH, followed by a second session with a VH having simulated awareness that can recall previous information and exhibit additional awareness capabilities.

4.1 Participants

The participants of this study consisted of 16 people with a nursing background. We achieved an actual power of 0.93 for the given sample size ($n=16$) from the G*Power analysis [23]. Refer to section 5.3 for more details about the G*Power analysis. Of the 16 participants, 15 identified themselves as females and 1 as male. The age range of the participants was between 18 and 25 years ($M = 20.63$, $SD = 1.69$). Regarding ethnicity, 6 identified as White, 4 as Hispanic, 2 as Caucasian, 2 as Asian, 1 as African American, and 1 as not Hispanic or Latino. 14 Participants were born and raised in the USA, 1 was raised in the USA, and 1 was born and raised in

Honduras. In terms of profession, there were 10 Certified Nursing Assistants, 4 nursing students, 1 Nursing Assistant, and 1 Resident Assistant. All participants had previous professional experience caring for older adults with an average experience of 1 year and 5 months. Among the participants, 7 were previously exposed to immersive technology such as AR and VR while 9 had never experienced any immersive technology.

4.2 Study Design

This study was approved by the Institutional Review Board at the New Jersey Institute of Technology (NJIT) and the University of Central Florida (UCF). We employed a within-subject approach where each participant participated in two interaction sessions with the simulation. One of the co-authors disseminated invitations for the research study with flyers and virtual invitations in the College of Nursing at UCF. The invitations had brief descriptions of the study, its location, and its duration. Each participant spent approximately an hour for the study where they interacted with the simulation and completed surveys about their experiences.

4.3 Study Setup

This study was conducted at the College of Nursing at YY. We set up the study room with a bed, two small tables, a room divider, a desk for the human controller, and three webcams at different corners of the room (see Figure 1). We decorated the small tables with flower pots, a table clock, a lamp, and a radio to give the setup a more natural look as an older care facility. The remote-controlled lamp and radio were used as the IoT devices. In the inner section of the room, the hologram of the VH was projected by the bed and the participants were asked to stand close to the character to interact with the VH (see Figure 1). A Bluetooth speaker, utilized as the source of the VH's voice, was placed on the small table by the bed. The room divider was positioned to create a semi-private space for the VH-Participant interaction section and to hide the setup of the human controller.

4.4 Study Procedure

Upon arrival, all participants were provided with a brief description of the study and the course of tasks they were supposed to do during their participation. They signed a consent form and completed a demographic survey at the beginning followed by interacting with the VH and completing questionnaires. The interaction sessions were divided into two scenarios separated by a short interval. Participants were provided with different sets of tasks for the two scenarios. Upon completion of the study, they received 50 dollars for participation.

4.5 Scenarios and Participants Tasks

The two scenarios were designed to insinuate that the VH is aware of its surroundings and can remember information from the previous conversation. We utilized IoT devices to accommodate the aspect of the VH's simulated awareness where the VH displayed the ability to control the IoT devices (i.e., a lamp and a radio). The VH also identified and commented on the colors of the participants' attire; the VH addressed the participants by their names in the second interaction scenario.

Participants were asked to enact a caregiver to the VH in both scenarios where the VH was an older female patient living in a geriatric care facility. After signing the consent form, participants put on the Hololens 2 and entered the private space to interact with the VH. They entered into the space where the lamp was already lit up and everything else was as described in the "Study

Setup” section. In the first scenario, the participants were asked to get introduced to the VH, to have any conversation they liked, and to encourage the VH to do some activities (e.g., playing a game). The VH asked the participants to turn off the lamp during their conversation and also asked the participants to turn on the radio before they left the space after the first scenario. After a short interval, participants returned to the space for the second interaction session. Participants were told that the VH was waiting for her family to visit today and they were supposed to inform her that her family was going to be late. Alongside, they were open to having any conversation with the VH if they liked. The VH welcomed the participants by their names and turned off the radio at the beginning of the second session. She also commented on the color of their attire. Participants informed the VH that her family was going to be late to visit her and they left the interaction space after the conversation finished. At the end of the second scenario, participants completed the surveys.

4.6 Measures

In this study, the participants completed two surveys that measured system usability and technology acceptance. We asked ten 5-point Likert scale questions, responses ranging from “strongly disagree” to “strongly agree”, from the System Usability Scale (SUS) tool [12]. From the Technology Acceptance Measurement (TAM) tool’s perceived ease of use dimension [17], we asked eight 4-point Likert scale questions, with responses ranging from “strongly disagree” to “strongly agree”. We asked the following three open-ended questions-

1. Please list any positives or things you liked while using the software.
2. Please list any negatives or difficulties or things you didn’t like while using the software.
3. What would you suggest for improving this software?

The open-ended questions were presented in written form at the end of the other survey questions, and the participants also provided their responses in writing.

5 RESULTS

We conducted a comprehensive analysis of data across four distinct categories: VH-Participant interaction duration, System Usability Scale (SUS), and Technology Acceptance Model (TAM) scores, and qualitative feedback provided by the participants. Specifically, we examined the duration of participant interactions with the VH during both experimental scenarios, quantified the VH’s response count, and evaluated participants’ task completion efficacy. We present the SUS and TAM scores, delineating various score ranges. We succinctly discuss the feedback received from participants concerning the system’s performance and usability.

5.1 Data Collection and Statistical Analysis

We collected data using three different methods: questionnaires, video recordings, and button click logs of the responses generated by the human controller. We collected participant responses to the system usability and technology acceptance scale questionnaires as described in the “Measures” section. We saved the logs of buttons pressed by the human controller with timestamps during the VHParticipant interaction scenarios. The logs illustrate the duration of each user’s interaction with the VH per session. We recorded the interaction sessions to observe the interactions for more detailed analysis. We conducted a power analysis to determine sufficient sample size, aiming for a power of 0.80 with

an alpha level of 0.05. Descriptive statistics, including means and standard deviations, were calculated to summarize the demographic characteristics and key variables. We performed the Shapiro-Wilk test for data distribution check followed by a non-parametric Wilcoxon signed rank test to analyze the SUS and TAM survey data. All data analyses were performed using JASP software.

The system usability scores were calculated by re-scaling responses from 0–4, summing these, and multiplying by 2.5. The re-scaling process involved adjusting the user’s responses. One was subtracted from the user’s score for odd-numbered items. The score was subtracted from five for even-numbered items. The sum of these re-scaled scores is then multiplied by 2.5, changing the overall range from 0–40 to 0–100. To assess the technology acceptance scores, we employed a reverse scoring technique for the negatively worded items by deducting the original score from 5. We then aggregated these scores with the rest of the item scores. The TAM scores range from 0 to 32. Additionally, we computed the mean and standard deviation and categorized the final scores into distinct ranges in ascending order.

5.2 Interaction Duration

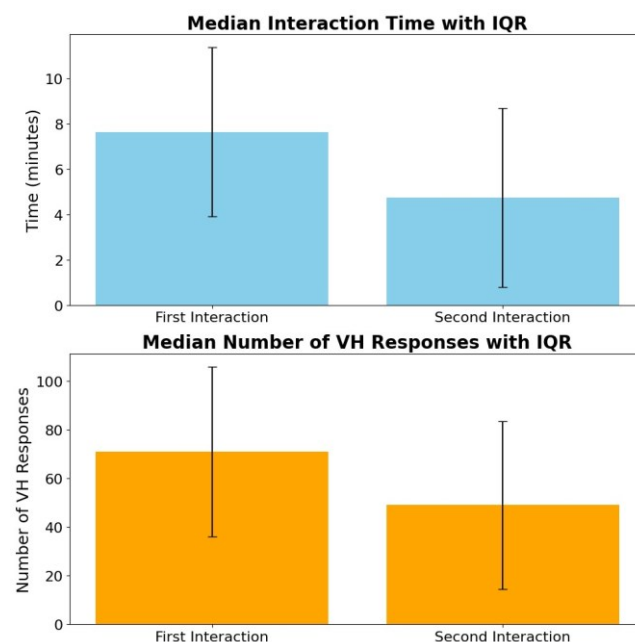


Figure 6: Error bar plot for Participant-VH Interaction Duration and VH response Count.

All participants completed the given tasks successfully during both interaction scenarios. Participants spent approximately 7 minutes 38 seconds on average interacting with the VH during the first scenario (SD=2 minutes 10 seconds) with 5 minutes 25 seconds being the least and 12 minutes 19 seconds being the highest amount of time spent. During the second interaction, participants spent less time than the first session (Wilcoxon signed-rank test, p -value < 0.05) with 4 minutes 44 seconds being the average amount of time (SD=1 minutes 57 seconds). The highest time spent during the second session was 8 minutes 59 seconds and the lowest spent time was 2 minutes 12 seconds (see Figure 6). The typical latency of the VH’s responses was 1-3 seconds. However, there were a few outlier cases of the VH response delay that ranged between 5-10 seconds for the first couple of participants due to the human controller’s limited practice.

The VH exhibited an average response count of approximately 71 during the first scenario ($SD = 20$), whereas in the second scenario, this count decreased to 49 ($SD = 20$) (see Figure 6). Notably, in the first scenario, the VH provided a minimum of 49 responses and a maximum of 120, while in the second scenario, the response count range spanned from 27 to 96. It's worth noting that the variation in responses could be linked to the novelty and exploration during the first session, while the second session was more predictable and familiar.

5.3 System Usability Scores

We used the non-parametric Wilcoxon signed-rank test to test for any differences between the usability scores achieved with our procedure and the established System Usability Score (SUS) of 68. Given the small sample size ($n=16$), it is not clear if our data were normally distributed (per the Shapiro-Wilk test for normality), hence our choice of the Wilcoxon signed-rank test [35, 36]. A power analysis using the G*power software showed a power of 0.93, based on an effect size of 1.0 (given by matched rank biserial correlation) and a type I error probability alpha of 0.05.

In the context of system usability, a score of 68 (out of 100) is typically regarded as average, with scores exceeding 68 deemed above average and those falling below 68 viewed as below average [12]. The simulation achieved an average system usability score of 78.44 ($SD = 12.04$). The minimum score recorded was 57.5, while the maximum score reached the upper limit of 100 (see Figure 7). As mentioned earlier, we performed a one sample Wilcoxon signed-rank test comparing our sample mean to the established average SUS score of 68. The test statistic (w) was 17 ($p\text{-val} < 0.006$), hence, we reject the null hypothesis and conclude that the system's usability is statistically significantly different from the average score of 68. We grouped the scores into four distinct ranges, with the participant ratings distributed as follows: 25% rated between 57.5 and 70, 37.5% between 71 and 80, 12.5% between 81 and 90, and 25% between 91 and 100.

A quarter of the participants rated the system below average, while the remaining three-quarters assigned it an above-average score. Within the above-average category, the scores were evenly distributed, with half of the participants rating the system between 71 and 80 and the other half assigning scores between 81 and 100. The interpretation of these findings suggests that the system has a good level of usability and is user-friendly to most of the participants with 37.5% of the whole population rating it above 80 having a high level of satisfaction with the system. With a few suggestions to increase the scope of responses, incorporating additional interactive features into the VH, and eliminating instances of speech overlap between the VH and the participants, the system was perceived as very accessible by the participants.

5.4 Technology Acceptance Model Scores

The Technology Acceptance Model does not have a universally defined average score as it varies based on the context, the specific technology being evaluated, and the user group involved. However, the model focuses on two factors: Perceived Usefulness and Perceived Ease of Use [17]. In this study, we assessed the perceived ease of use and the system attained an average score of 28.5 out of 32 ($SD = 2.63$). The minimum and the maximum scores were 25 and 32 respectively. In other words, our simulation attained an average score of 89.1%, with a minimum of 78.13% and a maximum of 100%. A significant 68.75% of the participants rated the system

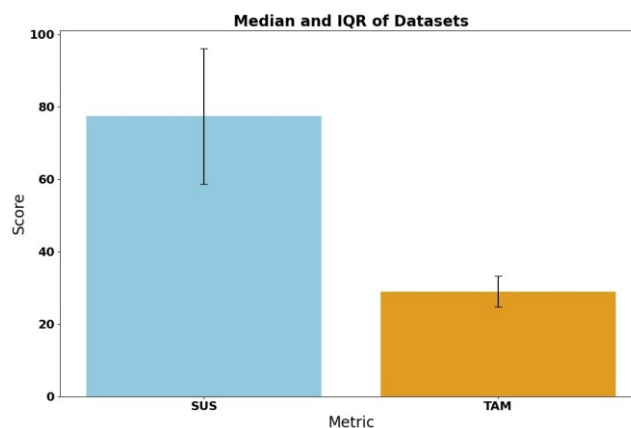


Figure 7: SUS and TAM scores error bar plot.

between 84.37% and 100%, while the remaining 31.25% rated it within 81.25% (see Figure 7).

While there is not a universally accepted average score for the Technology Acceptance Model, we considered 26, 27, and 28 (which are above 81.25% of the maximum possible score) as our hypothesized means. We then performed a one-sample Wilcoxon signed-rank test comparing our sample mean to the hypothesized means. The test statistics (w) were approximately 9.0 ($p\text{-val} < 0.006$), 18.0 ($p\text{-val} < 0.03$) and 53.5 ($p\text{-val} < 0.50$). We can infer, based on these results that our system's acceptability is significantly different than the hypothesized means of 26 and 27 for a confidence interval of 95%. For further analysis, we divided the scores into three distinct ranges. The participant ratings distribution within these ranges is as follows: 31.3% rated between 24 and 26, 25% between 27 and 29, and 43.8% between 30 and 32.

5.5 Qualitative Analysis

We performed a thematic analysis of the participants' responses to the open-ended questions to extract positive and negative patterns in participants' feedback. Participants provided feedback on the simulation software, highlighting its positive aspects, challenges, and areas for improvement. They expressed their positive experience with the software's ease of use, interactivity, realism, personalization, visual and auditory clarity, variety of responses, and focus on bedside manner. Following is a quote from one of the nursing students about the realism of the simulation—

"I liked how realistic the software was. It seemed more realistic than our simulation dummies used during simulation"

However, they also reported difficulties such as experiencing awkward pauses during interactions and formulating questions. They expressed a desire for more interaction options, more specific responses, and improvements in the virtual character's voice and visibility. According to one participant—

"The biggest negative was that she would pause when talking like she was done so then I would talk but it would turn out she wasn't done and she would continue to talk over me. Also, some answers were limited but not many, she was able to answer most of my questions as normal."

For improvements, participants suggested a wider variety of responses, smoother communication flow, more events for interaction, more voice-dependent responses, and the ability for the character to move around. They also recommended adjustments to the patient's dimensions, incorporation of artificial intelligence components, and more organic responses. Suggestions also included having family members in the environment, having the patient in bed at some point, and having items to interact with the patient. One participant suggested—

"I think being able to have the character move around and do things would be interesting and enhance the experience."

6 DISCUSSION

Our embodied VH simulation offers a lifelike interactive experience that can be employed in geriatric settings and beyond, thereby facilitating more efficient learning for students. Despite certain limitations, our simulation holds significant potential in improving verbal communication training across various fields.

6.1 System Usability

The straightforwardness of the system made it easy for the participants to have a conversation without having to go through any other interface or perform any tasks. All participants initiated the conversation and most could locate and switch off the lamp when asked by the VH, indicating ease of use or clarity of instructions. Existing works [45, 34, 33] focus more on the outcome (e.g., improving communication skills, empathy, engaging the users in the interaction) of their systems whereas making the system more userfriendly and accessible is less focused on. Focusing less on userfriendliness and accessibility is an issue, specifically, for the nursing students' user base coming from a non-technical background that could possibly affect the outcome of using these systems. Additionally, the healthcare sector is increasingly using AR systems to train their employees (i.e., caregivers, nurses, healthcare providers) who do not have much expertise in using AR systems. Hence, making AR systems easier to use and more accessible could lead to improved training outcomes and draw more users to use AR for training.

6.2 Technology Acceptance

The Technology Acceptance Model scores suggest a high level of acceptance of the system among a majority of the participants. Furthermore, when the VH requested the participants to switch off a lamp during their interaction and play a 20-question game, all participants complied. Participants' compliance suggests their adherence to and potential influence by the system. Compliance of participants could be interpreted as an indication of their acceptance of the system. Compliance of participants could be interpreted as an indication of their acceptance of the system [62, 4]. Existing training methods, as described in the literature review section, include training caregivers with AI based systems with no technical person's intervention and in some cases hired actors acting as the patient. However, these methods pose unique challenges. For example, state-of-the-art Large Language Models powered chatting agents may require a large amount of data to generate precise responses [40, 3, 60], but it's also possible that smaller, better-tuned models could be effective. However, fine-tuning models trained on smaller datasets could lead to overfitting and such models may not be very accurate in response generation in the test cases which needs special focus to address these issues. To the best of our knowledge, not too many datasets are available

for geriatric patient care. This could be interpreted as the geriatric care facilities are not very well prepared to accept these technologies at the moment.. Hired actors are also used as patients in training, however, finding old actors, preparing them for training scenarios, actor performance during scenarios, and the need for going out of script can be a complicated process to achieve and hence less acceptable in this field.

6.3 Qualitative Feedback

Based on verbal feedback, participants generally expressed a positive experience interacting with the VH. In our sample, two nursing students found the VH interaction superior to their mannequin simulation classes due to the limited interactive capabilities of the mannequins. While some mannequins offer only audio feedback with no expressions or body gestures, and others can depict expressions but are limited in movement and natural conversation, the VH can engage in human-like conversations, displaying emotions and body gestures simultaneously. This capability might have potentially enhanced user engagement by providing the participants with a non-robotic experience. The duration of VH-participant interaction could be an indicator of an increased level of engagement. Although there is no universally agreed-upon conversation duration indicative of a good experience, the interaction duration with our VH exceeded our expectations. Despite being assigned only a few tasks in the first and second sessions, which could have been completed within a few minutes, participants spent approximately 8 minutes in the first session and about 5 minutes in the second. As mentioned earlier, the difference in conversation duration may be attributed to the novelty and exploration during the initial session, whereas the second session followed a more predictable and familiar pattern. All participants completed a 20-question game with the VH, some shared their life stories and asked the VH questions about her life. We interpret these behaviors as indicators of participant engagement and satisfaction with the VH communication experience. However, it's important to note that these observations are based on a small sample of nursing students in our study, and further research with a larger sample size is needed to generalize these findings.

7 LIMITATIONS

This pilot study was designed to evaluate our simulation, and it was conducted with a relatively small sample size of just 16 participants. Additionally, the participant pool was predominantly female, with only one male participant, which we acknowledge as a potential limitation of the study. This was our first prototype of the system where the focus was on the conversation. We started with limited responses and during the study we collected conversations for the first time between caregivers and geriatric patients, which will enhance the range of organic responses. Other current limitations include speech overlap between participants and the VH and the VH's limited interaction with the environment and mobility features. The issue of speech overlap occurred at the operational level (i.e., human controller). This issue can be optimized with increased practice of the operator. The speech overlap issue could also have been resolved by having a stop-talking feature.

8 FUTURE WORK

Future enhancements of the simulation could proceed in several directions. Initially, our focus will be on rectifying the existing limitations in the system to enhance its robustness. With these improvements, we anticipate conducting a more extensive study involving a larger and more diverse population. This will allow us to ascertain the system's generalizability across various fields and

determine whether its usability and acceptability remain consistent with a broader user base. Additionally, we shall broaden the set of responses and integrate an automated response controller replacing the human-in-the-loop approach. Automating the response generation could be achieved through machine learning algorithms trained on the collected interaction data. We also plan to expand the set of VH responses and incorporate more natural language processing capabilities to make interactions more dynamic and contextually appropriate. To address issues such as speech overlap, we are considering implementing real-time feedback mechanisms. For example, a visual indicator when the VH is processing input or speaking could help manage the interaction flow. Lastly, we aim to provide comprehensive documentation, configuration settings, and step-by-step guidelines for setting up the system and conducting the experiments.

9 CONCLUSION

In this article, we presented an embodied VH with simulated awareness capabilities within an immersive Augmented Reality environment. We evaluated the technology in a pilot study with caregivers of older adults to gauge the system usability and technology acceptance of our framework. The findings indicate that the majority of the participants deemed the system as user-friendly and easy to use, as well as, rated the system as highly acceptable. Despite a few limitations of the system, attributable to it being in its preliminary stage, participants appeared to like interacting with the system and appreciated the user experience. We believe our system has the potential to enhance the training of geriatric caregivers by providing realistic job scenarios. This could assist nursing students in making informed decisions about entering the profession, potentially leading to a reduction in caregiver turnover.

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