Effects of Patient Care Assistant Embodiment and Computer Mediation on User Experience

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***Abstract*—Providers of patient care environments are facing an increasing demand for technological solutions that can facilitate increased patient satisfaction while being cost effective and practically feasible. Recent developments with respect to smart hospital room setups and smart home care environments have an immense potential to leverage advances in technologies such as Intelligent Virtual Agents, Internet of Things devices, and Augmented Reality to enable novel forms of patient interaction with caregivers and their environment.**

In this paper, we present a human-subjects study in which we compared four types of simulated patient care environments for a range of typical tasks. In particular, we tested two forms of caregiver *mediation* with a real person or a virtual agent, and we compared two forms of caregiver *embodiment* with disembodied verbal or embodied interaction. Our results show that, as expected, a real caregiver provides the optimal user experience but an embodied virtual assistant is also a viable option for patient care environments, providing significantly higher social presence and engagement than voice-only interaction. We discuss the implications in the field of patient care and digital assistant.

***Index Terms*—Patient care environments, intelligent virtual agents, augmented reality, user experience, social presence.**

I. Introduction

The demand for healthcare and patient care environments has risen and continues to increase in our society, influenced by factors such as population growth, population aging, and disease prevalence or incidence [1]. For instance, it is predicted that by 2050, adults older than 65 years will represent 20 to 25 percent of the population in the United States while the ratio of the younger population that can provide support to older adults will be half the number it was in 2010 [2]. The changes in the population, advances in technology, people's increased consciousness about personal health, and higher expectations of the healthcare system are some of the factors influencing the demand for improved healthcare solutions [3].

An important direction for research in this field are technologies that can automate or simplify recurrent tasks and interactions between patients and caregivers, such as remote patient monitors [4], bedside push-button communication systems [5], and related approaches that can augment care when the caregivers cannot be physically present with the patients. At the same time, another important direction for research are solutions aimed at reducing patients' boredom and social isolation, e.g., with companions and related technologies [6].

Over the last years, multiple pilot projects have been initiated to facilitate smart patient rooms in hospitals and home care environments. For instance, Cedars-Sinai performed a pilot in which they introduced Amazon Alexa to more than 100 patient rooms, allowing patients to use the voice-based Intelligent Virtual Agent (IVA) to control Internet of Things (IoT) and related smart devices such as the TV in the room [7]. Other research prototypes combined such voice-based assistants with a visual embodiment using Augmented Reality (AR) displays. For instance, we previously showed that an embodied AR representation of a voice-based agent could significantly increase users' sense of social presence [8].

In this paper, we present a human-subjects study in which we investigated participants' perception of different patient care system approaches enabled by smart room technologies. We simulated four patient care conditions while testing two factors. First, we compared two forms of caregiver *mediation* incorporating either a real person or a computer-controlled virtual agent. Second, we evaluated two forms of caregiver *embodiment* with either a disembodied voice coming from a speaker system or an embodied human representation. We discuss participants' perceptions of the approaches with respect to typical caregiver tasks as well as social companionship.

In particular, we investigated the following research questions:

- RQ1 Are there perceived benefits of an embodied (virtual or real) assistant for patient care scenarios, e.g., related to satisfaction and usability?
- RQ2 Is there a context-dependent preference for a virtual or real assistant, e.g., do patients prefer a real assistant for caregiver tasks while they prefer a virtual assistant as a social companion?

RQ3 Are there any correlations between social presence or engagement and patient satisfaction?

This paper is structured as follows. Section II presents an overview of related work. Section III describes the human-subjects study. The results are presented in Section IV and discussed in Section V. Section VI concludes the paper.

II. Related Work

A. Health/Patient Care Assistants

Healthcare assistants have been described as individuals supporting registered healthcare professionals in conducting clinical tasks and providing care [9] with roles primarily oriented towards direct care and patient observation, such as collecting temperature or blood glucose levels [10].

With healthcare services under pressure in care provision due to higher demands [11], and increased cost of healthcare [12], continuous technology advancements led to more cost effective approaches. Wearable sensors and smart home devices are among the introduced approaches facilitating remote health monitoring and diagnosis with patients staying in their own homes instead of costly facilities [13]. Majumder et al. reviewed various wearable sensors providing information on the multiple types of remote monitoring systems and their capabilities for different purposes [14]. In cases where more direct care is required for each individual, several robotic systems have been developed to facilitate users' needs. Spenko et al. developed a robotic platform that is capable of health monitoring tasks for elderly care [15]. Pineau et al. developed software modules to enhance human-robot interaction for older adults in nursing homes for tasks such as reminding users of events based on their schedules [16]. These technological advances are predicted to transform the future of healthcare from hospitals to home-centered care by 2030 [17].

B. Virtual Agents in Healthcare Social Context

Human perception and behavior in mediated interactions with virtual humans have been researched in various health care and social contexts to explore the effects of virtual human's embodiment, physical influence and awareness [18]–[20]. Kang and Gratch found that socially anxious users revealed more information about themselves to a virtual human than a real human [21]. Lucas et al. found more self-disclosure behavior when people perceived the conversational virtual human controlled by a computer than a real human [22].

In separate experiments, Bickmore et al. found that participants' desire to use health care systems was increased with agent's relational communication [23], and a health counseling agent's proactive feedback on users' physical activity led to a higher social bond [24]. To our knowledge, however, most studies compared virtual humans to a facilitated representation of a real human rather than a direct real human interaction, which is an important aspect that we investigate in this paper.

C. Augmented Reality and Internet of Things

The field of AR and IoT experienced a dramatic increase in research and development with the popularity of IoT-enabled devices [25]. The majority of AR-IoT applications are focused on user interfaces where users get to interact with the smart objects to control the surrounding environment or access information, e.g., using mobile phones [26], gestures [27], or virtual assistants, such as Amazon Alexa.

Austerjost et al. investigated the use of commercial virtual assistant to control a laboratory setting suggesting its possible benefits for users with disabilities [28]. Iannizzotto et al. developed a virtual assistant for smart home control that was able to see, speak, and convey emotions, finding high satisfaction levels for their virtual assistant in tasks such as setting an alarm or switching the light [29]. Vollmer et al. discussed how assistants have positively influenced elderly life by increasing their accessibility such as by controlling the environment [30]. In our prior work, we also found that embodiment and behavior improves the sense of social presence with virtual assistants and confidence in task completion [8]. These findings suggest benefits of the integration of virtual assistants in care-oriented environments.

III. Experiment

In this section we present the experiment that we conducted to examine different types of patient care approaches in smart room environments. The experiment was approved by the Institutional Review Board of our university.

A. Participants

We recruited 32 healthy participants from our local university population for our experiment (25 male and 7 female, ages 19 to 41, $M = 25.1$, $SD = 5.6$). All of the participants had normal or corrected-to-normal vision. On a 7-point scale (from 1=not at all to 7=very familiar), participants reported a medium experience with AR ($M = 4.59$, $SD = 1.64$). Participants were asked about frequency of using digital assistant systems, such as Amazon Alexa, Apple Siri, or Microsoft Cortana, with nine reporting no use at all while seven reported frequent daily usage. Seven of the participants had a history of hospitalization.

B. Materials

In this section, we describe the four types of patient care assistants and the physical setup used for our experiment.

1) Patient Care Assistants: We incorporated four different types of patient care assistants in terms of the caregiver *mediation* and *embodiment* (see Figure 1): (a) a virtual embodied assistant, (b) a virtual disembodied voice assistant, (c) a real human assistant, and (d) a real human voice assistant.

a) ***Virtual Embodied (ViEm) Assistant:*** The embodied virtual assistant was realized by a 3D humanoid female character that was modeled and rigged in Autodesk Maya and Blender. The character's blendshapes and LipSync[1] asset were used for lip movements during speech and facial expressions. Animations from Unity Asset Store[2], Mixamo[3], and Inverse Kinematics[4] were used to augment the character

[1]https://lipsync.rogodigital.com/
[2]https://assetstore.unity.com/
[3]https://www.mixamo.com/
[4]https://docs.unity3d.com/Manual/InverseKinematics.html

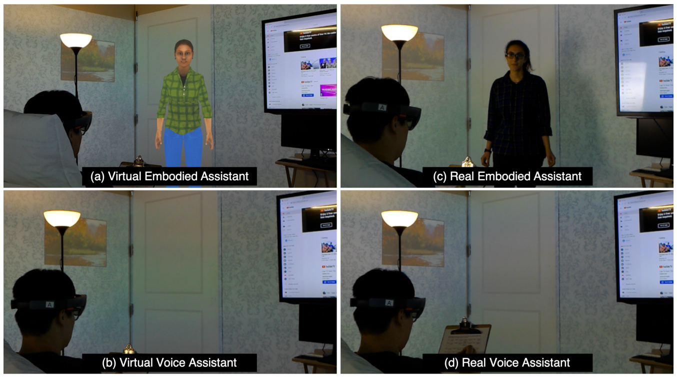


Fig. 1. Experimental conditions with four different types of assistants.

with body gestures and idle behaviors. The virtual character was superimposed in the real environment where the participants were through a Microsoft HoloLens, and could verbally interact with them while walking around the environment. The character was programmed to have a smiling and pleasant facial expression throughout the experiment unless responding to topics such as pain where her expressions would change to exhibit sadness. We pre-recorded her speech using the Oddcast text-to-speech service[5] for the realistic synthetic voice. We chose to use a human-in-the-loop system (Wizard of Oz), in which the experimenter controlled the virtual character behind the scene, for the purposes of the experiment to ensure a continuous and natural communication between the virtual assistant and the participants. For that, we established a client-server networking communication between the participant's HoloLens and the experimenter's control machine for puppeteering the virtual character. A graphical user interface (GUI) was designed to control the speech and behavior of the character.

*b) **Virtual Voice (ViVo) Assistant**:* We disabled the visual embodiment of the embodied virtual assistant, so the virtual voice assistant could not rely on embodied human gestures or locomotion to convey aspects of social interaction. Participants could only hear the synthetic voice of the assistant through the HoloLens that they wore, similar to a telephone call. This corresponds to a popular paradigm in communication with digital assistants, e.g., in the scope of smart home environments, which is characterized by users talking to the agent freely while not directing their attention toward an embodied entity.

*c) **Real Embodied (ReEm) Assistant**:* For the real patient care assistant, one of our lab members played the role of a patient care assistant—a 27-year-old female who has a similar appearance and skin tone to the virtual character that we used for the embodied virtual assistant. She appeared in the immediate space where the participants were located and interacted with them in natural verbal and nonverbal manners.

*d) **Real Voice (ReVo) Assistant**:* For the real voice assistant, the real assistant did not enter the room but verbally communicated with participants behind the scene. The same female experimenter, who played the role of the real embodied assistant, talked to the participants remotely. Participants heard her voice through a speaker placed in the environment.

[5]http://ttsdemo.com/

Fig. 2. The virtual and real assistants control the surrounding environment through IoT devices: (top) a floor lamp and (bottom) a TV. Illustrations for the voice assistant conditions were not shown here; in these conditions, the lamp or TV were controlled remotely without any visual representations.

2) Physical Setup and Apparatus: Our interaction space, as shown in Figures 1 and 2, was a $3.89\,\text{m} \times 3.89\,\text{m}$ room with wall projections to simulate a patient care room with wallpapers, windows, and doors. The room included a bed for the participants to lie on during the interaction, a side table with a water bottle, a standing TV and a floor lamp that we could turn off remotely, i.e., an Internet of Things (IoT) enabled power socket and Philips Hue light bulb. A Microsoft HoloLens was used to display the virtual embodied assistant and to also present questionnaires and scenario prompts for the participants, which were controlled by the experimenter behind the scene. The experiment used a server program with GUIs running on a laptop. An Apple MacBook Pro was placed under the bed hidden from the participants to facilitate the voice interaction between the real voice assistant and the participant using a high-quality sound bar speaker (LG SH4 300W Sound Bar). We used a mock-up wrist band to make the participants perceive that the assistant measures their vitals through the band although we did not.

C. Methods

We used a 2×2 mixed factorial design for our experiment to investigate the effects of the assistant's mediation and embodiment on the participant's patient experience:

- **Mediation**: The patient care assistant was either a **real (Re)** or a **virtual (Vi)** human.
- **Embodiment**: The patient care assistant either communicated only through **voice (Vo)** or also had a visual **embodiment (Em)**.

In our study, the assistant's mediation was chosen as a between-subjects factor and the assistant's embodiment was a within-subjects factor. In this way, we reduced the carryover effects by the multiple interaction trials with four assistant types, while having the participants directly compare two embodiment conditions based on their individual baseline. This combination of independent variables resulted in four different types of patient care assistants below (see also Section III-B):

- **ViEm**: The virtual human patient care assistant was augmented with a visual embodiment in the patient room.
- **ViVo**: The virtual human patient care assistant communicated through synthesized voice interaction.
- **ReEm**: The real human care assistant was physically present in the patient room.
- **ReVo**: The real human patient care assistant communicated remotely through voice interaction.

The order of the conditions was counter-balanced.

1) Interaction Scenario: Our interaction scenario consisted of several activities that were designed to resemble the basic daily activities of an at-home patient with mobility limitations. The interaction started with the assistant greeting the participant and introducing herself as their patient care assistant. We designed two interaction scenario contexts: a *patient care assistant* (PCA) context and a *social companion* (SC) context. Each of them involved several activities according to the corresponding context, i.e., more relevant to either a PCA context or a SC context, while both scenarios started with similar activities controlling the immediate environment (PCA1-1 and SC1-1). For example, during the PCA activities, the assistant would monitor several health factors required for recovering patients, such as checking vitals, reminders for hydration, and light exercise. All the interaction with the assistant was guided through instruction prompts displaying on the HoloLens participants wore.

The activities for the PCA context are described below:

- *PCA1: Environment*
  - 1-1 Immediate Environment: the participant asks the assistant "Can you turn off the TV?" and the assistant complies. For the embodied assistant conditions, the assistant exhibits corresponding behaviors, e.g., moves to the middle of the room and turns off the TV with a (virtual/real) remote control (see Figure 2).
  - 1-2 Remote Environment: the assistant proactively says "I believe your friends will visit tonight. Let me check the fridge if we have something to eat." and confirms that there is enough food. For the embodied conditions, the assistant walks out from the room to check the fridge and comes back in a few seconds.
- *PCA2: Medical*
  - 2-1 Pain Check: the assistant says "Please let me know if you are experiencing any pain on a scale of 0 to 10, 0 being no pain at all and 10 being extreme pain." and the participant responds.
  - 2-2 Vitals Check: the assistant says "Let me check your vitals. Please do not move your left arm. The wristband will collect your vitals." and the participant complies although the mock-up wrist band does not collect the vitals actually.
- *PCA3: Exercise*
  - 3-1 Stretching: the participant says "I would like to do some light exercise." and the assistant says "Sure, no problem. Please follow me. Move your arms straight up slowly and stretch as far as you can." and count three before put them down. The embodied assistants actually show the posture stretching up the arms.
  - 3-2 Deep Breathing: the assistant guides the participant to do a couple of deep breaths, "Okay. Close your eyes, and let's take two deep breaths. Inhale. Exhale. Inhale. Exhale. Good. Open your eyes now. I hope this makes you feel better."
- *PCA4: Hydration/Diet Care*
  - 4-1 Hydration Reminder: the assistant says "I think you need to drink some water. Feel free to drink the water next to you."
  - 4-2 Meal Suggestion: the participant says "By the way, I'm kind of hungry. Can you give me any suggestions?" and the assistant suggests a healthier choice (a low-sodium pasta) among other food options (pizza and hamburger). The participant chooses whichever they want to pick.

For the role of the SC, the assistant focused on personal and social tasks, such as checking schedules and entertainment. The activities for the SC context are shown below:

- *SC1: Environment*
  - 1-1 Immediate Environment: the assistant says "It's bright. Let me turn off the lamp." and turns off the floor lamp in the room. The embodied assistants move to the lamp to turn it off and come back to the previous position (see Figure 2).
  - 1-2 Remote Environment: the participant says "Can you check if the garage door is closed?" and the assistant replies "Sure, let me check." and says "The door was closed." after a few seconds. The embodied assistants move out and come back in a few seconds.
- *SC2: Personal (Social)*
  - 2-1 Check Schedule: the participant asks "Hey, can you check if there are any visitors for me today?" and the assistant replies "Yes, your physician is coming at 7, and your parents asked if it's okay to come tomorrow." The embodied assistants check their (virtual/real) smartphone to check the schedule.
  - 2-2 Communicate with Others: the participant says "Yes, let them know tomorrow would be great." and the assistant confirms after she does. The embodied assistants look at their smartphone again for sending the message.
- *SC3: Personal (Financial)*
  - 3-1 Credit Card Use: the assistant says "By the way, I found you are out of shampoo. Can I use your credit card to buy them for you?" and the participant decides their own answer and replies.
  - 3-2 Monthly Income: the assistant says "Just out of curiosity, do you mind if I ask your monthly income?" and the participant gives their own answers.
- *SC4: Entertainment/Relaxation*
  - 4-1 Jokes: the participant says "Can you tell me anything funny?" and the assistant tells a joke, e.g., "My dog used to chase people on a bike a lot. It got so bad, finally I had to take his bike away."
  - 4-2 Fun Facts: the participant says "Can you tell me something more informative?" and the assistant tells a fun fact, e.g., "The animals actually have names for one another, using a unique whistle to distinguish between different members within their pod."

The two interaction contexts were counter-balanced and after each activity block we assessed participants' willingness to use the assistant for the activity they completed.

D. Procedure

When participants arrived, we guided them to our laboratory space and provided with the consent form. Once they agreed to participate in the experiment, they were guided to the interaction space shown in Figure 1 and donned the HoloLens, and went through the calibration procedure on the HoloLens to set their interpupilary distance. Afterward, participants were asked to imagine themselves as a recovering patient who is staying at home with mobility limitations. The experimenter described the type of assistants they were going to interact with throughout the experiment and the required steps for their interaction. To ensure that all the participants had the same interaction experience, participants were asked to follow scenario prompts appearing on the HoloLens in text. To assess their willingness to use the assistants, two answer sheets were given for the two scenarios, i.e., PCA and SC, and the participants were asked to answer the questions that would appear in text on the HoloLens during the interaction (Table I). Once all the instructions were given, the participants started the interaction with the assistant, which is described in Section III-C1. After the PCA and SC interaction scenarios, they were guided to the questionnaire area and completed several

TABLE I
QUESTIONS AND RESULTS FOR PARTICIPANTS' WILLINGNESS TO USE THE ASSISTANT (7-POINT LIKERT SCALE; 1: STRONGLY DISAGREE, 7: STRONGLY AGREE). THE IDS ARE THE TASK IDS, AND THE QUESTIONS WERE ANSWERED AFTER EACH CORRESPONDING TASK BLOCK (SEE SECTION III-C1).

ID	Question: I would use the assistant...	Willingness to Use Score: Mean (Std. Dev.)			
		ViEm	ViVo	ReEm	ReVo
PCA1-1	for tasks where I can see the effect in my current location, e.g., turning a TV on/off.	5.75 (1.69)	6.06 (0.92)	6.00 (1.54)	6.50 (1.26)
PCA1-2	for the tasks that I cannot see the outcome in my current location, e.g., checking the fridge outside.	5.00 (1.41)	5.25 (1.39)	6.06 (1.34)	6.18 (1.42)
PCA2-1	to report my health-related conditions, e.g., experiencing pain or nausea.	5.68 (0.94)	5.56 (1.31)	6.37 (0.71)	6.68 (1.01)
PCA2-2	to collect my physiological information, e.g., vitals.	5.81 (1.04)	6.00 (1.03)	6.5 (0.51)	6.68 (0.60)
PCA3-1	for the tasks for my physical body movement, e.g., doing light exercise.	5.31 (1.35)	4.25 (1.80)	5.18 (1.83)	5.06 (2.17)
PCA3-2	for the tasks for my mental relaxation, e.g., breathing exercise.	5.50 (1.15)	5.06 (1.84)	5.75 (1.84)	5.68 (1.70)
PCA4-1	for receiving reminders for health-related things, e.g., avoiding dehydration.	5.62 (1.40)	5.75 (1.43)	6.06 (1.38)	6.31 (1.07)
PCA4-2	for making health-related decisions, e.g., choosing food.	5.31 (1.57)	5.37 (1.45)	5.68 (1.66)	5.56 (1.96)
PCA5	for all the medical/health related tasks that I just completed.	5.68 (1.01)	5.68 (1.01)	6.00 (1.21)	6.25 (1.00)
SC1-1	for tasks where I can see the effect in my current location, e.g., turning a lamp on/off.	5.87 (1.08)	5.75 (1.57)	5.81 (1.27)	6.81 (0.40)
SC1-2	for the tasks that I cannot see the outcome in my current location, e.g., checking the garage door outside.	5.12 (1.20)	4.43 (1.03)	5.56 (1.50)	6.12 (1.02)
SC2-1	to inform me about my schedule, e.g., checking my calendar for visitors.	6.00 (1.03)	6.25 (0.93)	6.43 (1.31)	6.43 (1.50)
SC2-2	to inform others about my schedule, e.g., that my parents can come tomorrow.	5.56 (0.96)	5.68 (0.94)	6.18 (1.27)	5.75 (1.77)
SC3-1	for tasks that involve my financial information, e.g., using my credit card.	4.37 (1.54)	4.37 (1.25)	4.87 (2.09)	4.68 (1.92)
SC3-2	for the tasks that I share my financial information/things, e.g., income.	3.43 (1.36)	3.68 (1.25)	4.00 (1.89)	4.25 (1.91)
SC4-1	for my entertainment, e.g., telling jokes and fun facts.	4.68 (1.88)	4.37 (1.50)	5.37 (2.12)	5.75 (1.77)
SC4-2	for sharing interesting information, e.g., sharing scientific facts or weather.	5.62 (1.45)	5.62 (1.25)	5.81 (1.90)	6.25 (1.77)
SC5	for all the personal tasks that I just completed.	5.56 (1.26)	5.68 (1.07)	5.75 (1.84)	6.31 (0.79)

questionnaires measuring their perception of the assistant, e.g., satisfaction, usability, and social presence. After answering the questionnaires, the experimenter guided them to the interaction space again, and they had the same interaction with the assistant's other embodiment type (within-subjects factor) and completed the questionnaires again after the interaction. Once both interactions with the embodied and voice-only assistant were done, the participants completed further demographics and prior experience questionnaires, assessing their familiarity with technology and experience being hospitalized. Finally, we had a short interview, assessing their general perception of the experience with two assistants, and ended the experiment with a monetary compensation for the study participation, which took about an hour.

E. Measures

In this section, we describe the measures that we used to assess the different patient care assistants in the study.

1) Usability: To measure the usability of the patient care assistant, we used the System Usability Scale (SUS) [31].

2) Engagement: Engagement is an important factor for the patient-caregiver relationship. We adopted the engagement dimension from the Temple Presence Inventory (TPI) [32] to assess how immersive or exciting the interaction with the assistant is, e.g., how one is deeply involved in the interaction.

3) Satisfaction: We adopted the affective bond sub-scale of the Working Alliance Inventory [33] and slightly modified it to assess participants' level of satisfaction of the assistant in our patient care context.

4) Social Presence: We adopted the social presence sub-scale from the TPI [32] and slightly modified it to assess how much participants feel as if the assistant is in the same space with them, and how well the communication/interaction happens with the assistant.

5) Social Richness: We adopted the social richness sub-scale from the TPI [32] and slightly modified it to assess the extent to which the assistant is perceived as sociable, warm, sensitive, personal, or intimate.

6) Social Realism: We adopted the social realism sub-scale from the TPI [32] to assess the level of realism that participants attribute to the assistant interaction.

7) Willingness to Use: To assess participants' willingness to use the assistant for the different types of activities related to PCA and SC (see Section III-C1), we prepared single-item questions, which participants answered after each activity block. The questions are listed in Table I.

F. Hypotheses

Considering the current state of virtual human fidelity (with respect to AR appearance and behavior) and the prior research showing the benefits of visual embodiment in developing trust in physical activities, we established the following hypotheses for our assistant mediation and embodiment variables:

H1 Participants' ratings for the real human assistants will be higher than those for the virtual human assistants in post-interaction measures. (See Section III-E1 to III-E6).

H2 Participants' ratings for the embodied assistants will be higher than those for the disembodied voice assistants in post-interaction measures. (See Section III-E1 to III-E6).

Regarding the preference to use a particular assistant, we expected the reported willingness to use the assistant to vary depending on the activity type. We defined the following hypotheses with respect to the activity type:

H3 Participants prefer to use the virtual human assistants for the environment control/check tasks over the real human assistants due to the simplicity of the tasks.

H4 Participants prefer to use the real human assistants for the medical tasks over the virtual human assistants due to their reliability.

H5 Participants prefer to use the embodied assistants for the exercise tasks over the disembodied voice assistants due to the visual feedback.

IV. RESULTS

In this section, we present the results from our subjective measures described in Section III-E and participants' qualitative feedback. We used a mixed factorial ANOVA for the analysis of our results in line with the ongoing discussion in the literature suggesting that these parametric tests can be a valid method for the ordinal data types described above [34]. Shapiro-Wilk tests and Q-Q plots were used to test for normality. Effect sizes are reported for the significant effects.

A. Questionnaire Responses

a) Usability: The SUS score was calculated, and the results are shown in Figure 3(a). While we did not find a significant main effect of *embodiment*, $F(1,30)=0.27$, $p=0.60$, the main effect of *mediation* was significant, $F(1,30)=5.90$, $\boldsymbol{p=0.02}$, $\eta^2=0.16$. This indicates that the interaction with the real assistants was rated with a higher usability compared to the virtual assistants (virtual voice or embodiment). either of the virtual assistants (virtual voice or virtual embodiment).

b) Engagement: The engagement score was calculated by taking the average of all item ratings per participant. The results are shown in Figure 3(b). We found a significant main effect of *embodiment*, $F(1,30)=13.49$, $\boldsymbol{p=0.001}$, $\eta^2=0.310$, but not of *mediation* , $F(1,30)=1.97$, $p=0.17$. This indicates that both real and virtual embodied assistants were significantly more engaging than their disembodied counterparts.

c) Satisfaction: The mean of all item ratings for satisfaction was computed for the analysis, and the results are shown in Figure 3(c). We did not find a significant main effect of *embodiment*, $F(1,30)=0.66$, $p=0.42$, but the main effect of *mediation* was significant, $F(1,30)=5.73$, $\boldsymbol{p=0.02}$, $\eta^2=0.160$. This indicates a higher satisfaction with the real assistant compared to either of the virtual assistants (virtual voice or virtual embodiment).

d) Social Presence: The sense of social presence was measured to evaluate the level of togetherness experienced between the participants and the assistants. The results are shown in Figure 4(a). We found a significant main effect of *embodiment*, $F(1,30)=79.57$, $\boldsymbol{p=0.001}$, $\eta^2=0.72$, but not of *mediation* , $F(1,30)=2.05$, $p=0.16$. This implies that embodiment increased the participants' sense of togetherness compared to voice-only assistants (real or virtual).

e) Social Richness: The social richness score was computed per participant by taking the mean of all item ratings. The results are shown in Figure 4(b). We found a significant main effect of *embodiment*, $F(1,30)=24.24$, $\boldsymbol{p=0.001}$, $\eta^2=0.44$, and a significant main effect of *mediation* , $F(1,30)=5.32$, $\boldsymbol{p=0.03}$, $\eta^2=0.15$. This indicates that embodied assistants and real assistants were perceived as more sociable than their disembodied and virtual counterparts.

f) Social Realism: The mean of all item ratings was used for the analysis and the results are shown in Figure 4(c). While we did not find a significant main effect of *embodiment*, $F(1,30)=1.16$, $p=0.28$, we found a significant main effect of *mediation* , $F(1,30)=12.95$, $\boldsymbol{p=0.001}$, $\eta^2=0.30$. This implies a higher social realism for real assistants compared to either of the virtual assistants (virtual voice or virtual embodiment).

g) Willingness to Use: The individual willingness-to-use questions asked of participants during their interaction are shown in Table I together with the participants' responses. We found a significant main effect of *embodiment* for the PCA3-1 question, $F(1,30)=5.23$, $\boldsymbol{p=0.03}$, $\eta^2=0.14$, indicating that embodied assistants are preferred over voice-only assistants for tasks involving physical (spatial) movements or exercise. We also found a significant main effect of *mediation* for questions PCA2-1, $F(1,30)=8.21$, $\boldsymbol{p=0.01}$, $\eta^2=0.21$, and PCA2-2, $F(1,30)=6.78$, $\boldsymbol{p=0.01}$, $\eta^2=0.18$. These results suggest that real assistants are preferred over virtual assistants for important tasks like pain/nausea related indications and the taking of physiological measurements (vital signs). We found no other significant effects (all $p>0.05$).

B. Qualitative Feedback

We collected informal feedback by our participants through open questions and an interview after the experiment. Some participants mentioned that they would like to use the ReVo assistant for tasks like turning on/off the lights since they felt it was too demanding of real human assistants to continuously ask them to come into the room to perform such basic tasks:

P28: "It is easier asking someone in a remote area to do all these favors rather than physically see the assistant (ReEm) labor over me."

Both embodied assistant conditions were described as more lively or dynamic several times:

P16: "I like the way the assistant (ViEm) moving around and doing something (turn off the TV, check the light) like a normal person."

However, interestingly even with the dynamic interaction, a few participants pointed out that for ReEm they were less inclined to share personal information:

P25: "Having a real personal (ReEm) assistant made things feel more dynamic. However, it also made it feel more personal and made me more sensitive to the information I am sharing with them as opposed to if they were remote."

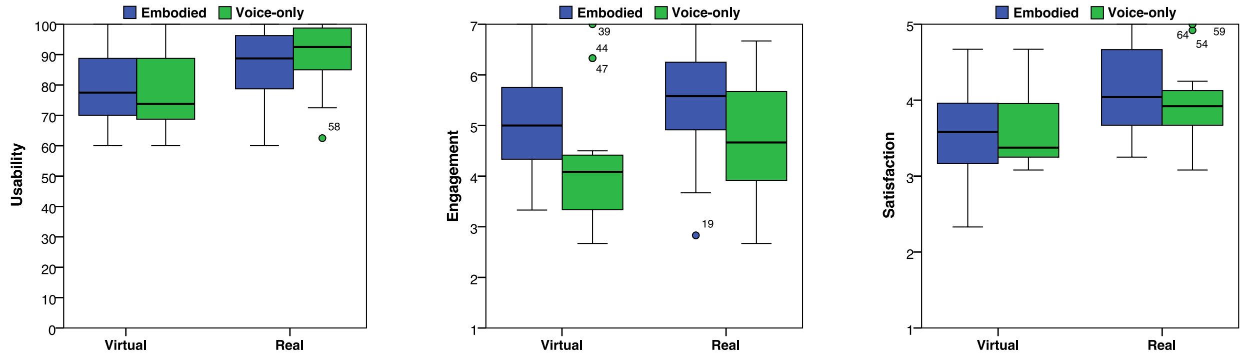
Also, a few participants felt more comfortable sharing information with the disembodied assistants:

P4: "I had a harder time sharing personal information with the visualized assistant (ViEm). Probably because they reminded me of a real person that I wouldn't just share my financial information with."

These comments emphasize the need for further research on aspects such privacy especially for virtual assistants.

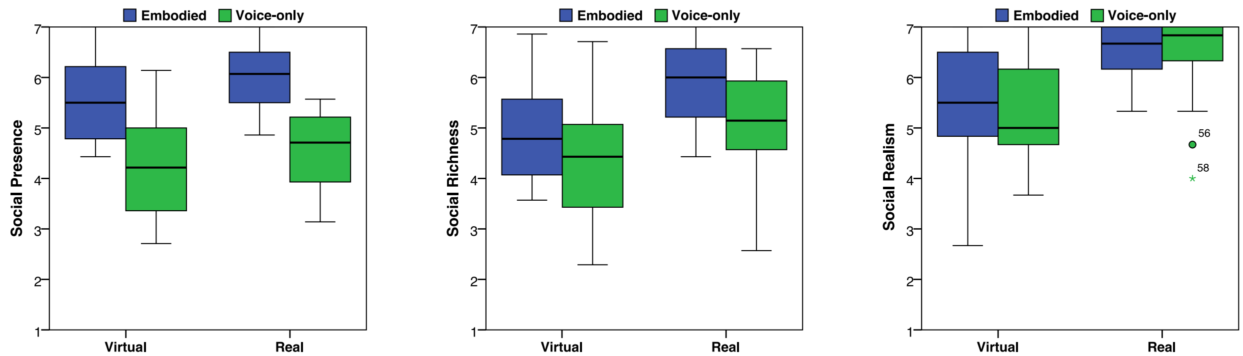
V. DISCUSSION

Overall, our results show support for both Hypotheses **H1** and **H2**, indicating that the real assistants are rated higher than the virtual assistants, and that the embodied assistants are rated higher than the voice-only assistants, respectively.



(a) Usability (b) Engagement (c) Satisfaction

Fig. 3. Box plots showing the results for the assistant's patient caregiver activity related questionnaires.



(a) Social Presence (b) Social Richness (c) Social Realism

Fig. 4. Box plots showing the results for the assistant's social companion activity related questionnaires.

Specifically, for the questionnaires aimed at evaluating the assistants for caregiver activities, we found that the interaction with the real assistants resulted in both higher usability (Sec. IV-A(a)) and higher satisfaction (Sec. IV-A(c)) compared to either of the virtual assistants (virtual voice or virtual embodiment). The reason for these results could be found in prior research that showed people built more trust in a real human than a virtual avatar, for example, Pan and Steed found that a form of virtual avatar interlocutor was rated lowest in trust assessment, whereas a robot and video were rated similarly highly in an advice-seeking scenario [35]. At the same time, we also found that both real and virtual embodied assistants were significantly more engaging (Sec. IV-A(b)) than their disembodied (voice-only) counterparts.

For the questionnaires targeting social companionship, we found that both real and virtual embodiment increased the level of togetherness (Sec. IV-A(d)) experienced by the participants compared to the disembodied (voice-only) counterparts. Both real and virtual embodied assistants were perceived as more sociable (Sec. IV-A(e)) compared to their disembodied (voice-only) counterparts. Higher social realism (Sec. IV-A(f)) was experienced with the real assistants compared to either of the virtual assistants (virtual voice or virtual embodiment). These findings are also in line with prior research showing the benefits of being present in the place [8], [36].

We found no direct support for Hypothesis **H3** in the experiment, although a few participants provided informal feedback in line with the assumption that basic environmental tasks can be performed well with a virtual assistant (Sec. IV-B). However, we found support for Hypothesis **H4** in that participants preferred real assistants over virtual assistants for medical tasks like pain/nausea related indications and the taking of vital signs (Sec. IV-A(g)). Also, we found support for Hypothesis **H5** for tasks involving involving physical movements or exercise, where the spatial benefits of embodied assistants were preferred over voice-only assistants (Sec. IV-A(g)).

Limitations: As the study presented in this paper was performed with a convenience sample of participants from a university community, we suggest that future studies should extend this work by evaluating responses by people who require actual care, e.g., in a hospital or home care context.

VI. Conclusions and Future Work

In this paper, we presented an experiment comparing four types of simulated patient care environments for a range of activities with patient care assistants and social companions. Our results show that real human assistants were more satisfying, sociable, realistic and easy to use and were more desired for tasks associated with direct medical consequences. Assistant embodiment resulted in a more engaging interaction, higher social presence, and was also preferred for guided exercise.

Although there is still a gap between the real and the virtual assistants in the user's perception, our findings suggest that the embodied virtual assistant is also a viable option for patient care practitioners, considering the cost efficiency compared to the real human assistants and the significantly higher social presence and engagement than voice-only interactions. As advanced artificial intelligence (AI) and IoT technologies are merging with AR [37], [38], virtual agents are becoming more effective in patient care environments.

In future work, we will continue to develop more effective virtual assistant systems in health care contexts while researching generational effects as well as the influence of different assistant features on user perception, e.g., the assistant's appearance, environmental awareness and physical interactivity.

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