Welcoming a Holographic Virtual Coach for Balance Training at Home: Two Focus Groups with Older Adults

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Abstract

We report on findings from two focus groups for designing an application for balance training at home with an augmented reality virtual coach. Following a User-Centered Design approach, we performed two focus groups with older adults at the early stages of development. Focus group participants were shown a prototype using a Meta 2 head mounted display. Their movements were tracked using a Kinect 2. The virtual coach gave balance training instructions and demonstrated their correct performance. Results suggest that, given the trade-offs of traditional health care, older adults are positive towards using an AR coach for their balance training.

Keywords: Augmented reality, balance disorder, physical therapy, virtual coach, Focus Groups

Index Terms: Human-centered computingHuman computer interaction (HCI); Applied ComputingLife and medical sciencesconsumer health;

1 Introduction

According to the World Health Organization (WHO) approximately one out of three people over 65 fall annually [5]. This rate increases to one in two people over 80 years of age. Falls can cause injuries and their consequent need for medical care results in more than 50% of all injury-related hospitalizations among older adults [16]. Hospital stays due to fall can be long (e.,g., 20 days for hip fractures) and even last for the rest of the patient's life (due to their frailty level). Furthermore, falls may lead to further restrictions in daily activities caused by post-fall syndrome [12] which includes immobilization, depression, and loss of autonomy. Consequently, falls and their related physical and psychological damages to the patients can create a major burden on health and social resources.

Early assessments and preventive interventions are highly recommended to mitigate the potential damages and costs as early as possible. The joint American and British Geriatric Society (ABGS) [14] as well as the National Institute of Clinical Excellence (NICE) UK have already published clinical guidelines for assessment and prevention of falls in older people [8]. Both guidelines, for instance, emphasize on customized exercise programs for strength, balance, gait, and coordination training which have been shown to be effective in reducing falls. According to the ABGS guidelines, these exercises should be included as part of a multi-component intervention and may even be considered as a single intervention. The NICE guidelines also recommend individually prescribed exercise programs which are monitored by a trained professional. However, access to specialized physiotherapists to monitor the performance of the exercises per individual introduces yet another limitation to such preventive interventions. There is therefore motivation to come up with innovative approaches for low cost individualized coaching.

We present a prototype designed to support clinical experts in prescribing and monitoring fall preventive exercises. The proposed prototype provides individualized exercise programs for balance training based on the NICE guidelines. The system provides a holographic virtual coach for training balance physiotherapy exercises and a motion capture module which facilitates monitoring of the correct performance of the exercises by motion capture and wearable sensors. In order to provide a system with optimal usability, we used the user-centered design (UCD) approach [9]. UCD suggests an iterative development circle which includes analyses of requirements, prototype implementation, and evaluation of the developed concepts. After each iteration, new insights will evolve and will lead to re-prototyping of user interface concepts until the specified usability goals are achieved. Therefore, the UCD approach involves the end users throughout the product development and testing process in order to ensure all the safety and user experience requirements in the final product. Following this approach, we organized two focus groups with a total of 52 older adults to evaluate our first prototype. In this paper, we report on the results and present our gained insights.

2 Related Work

UCD approach has already been employed for designing and developing health systems for the elderly. Harte et.al., [9] suggested a three-phase UCD methodology to enhance the usability and user experience of connected health systems. The first phase emphasizes the construction of a context of use document to report use cases, mock-ups, and user feedback. The second phase suggests an expert usability inspection and the third phase emphasizes classical user experience testings to improve the final prototype. They also reported an implementation of their methodology for the design and development of a system for fall detection in elderly. Another study [17] employed field studies to investigate the acceptance of a fall risk assessment wearable (in a form of a belt) device by older adults. They report that the combination of contextual information for fall risk assessment and practical fall prevention instructions can improve the acceptance of such assistive technologies. Furthermore, Albaina et. al. [6] presented a virtual coach in a form of an animated flower to encourage older adults to walk more. The users were also involved in the design and development process and provided their feedback in two focus groups and one field study. The results of their explorative study showed that elderly users enjoyed interacting with the flower virtual coach and would like to use it for a longer time. Although their virtual coach was not proven to be critical for motivating people, it was shown to add to the acceptability of the system.

In the realm of holographics coaches Anderson et al. presented

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YouMove. A holographic mirror that depicts a stick-figure coach superimposed on the practitioner's skeleton on the mirror. A disadvantage of that approach is that it requires a specialized installation and as such makes it difficult to be deployed at the homes of elderly. Katzakis et al. [10] presented a haptic device that attaches to the forearm and attempts to emulate touch from a virtual coach. An evaluation of their system reveals that, in line with the literature for visuo-haptic integration, visuals play a dominant role when information from other sensory modalities is ambiguous. The authors of that work also found that their device, when paired with appropriate visualisations of a virtual coach, helps improve the time participants took to reach certain postures [11]. This is part of the reason why we focused on a virtual coach for our work.

3 Balance Physiotherapy Hologram

In this paper we further explore the concept of virtual avatars for balance training coaching by implementing and comparing a multitude of augmented reality (AR) avatars, as these have several advantages over flat visualizations on monitors. The stereoscopic view of an AR display allows the participants to quickly identify 3D poses in space, while also being able to look at the instructor from any angle. It is even possible to step inside of an avatar and see the instruction from the first perspective, removing the cognitive load of mental rotations.

The first prototype of the balance physiotherapy hologram (see Figure 1) was developed for the Meta 2 head-mounted display (HMD) and Kinect 2 using Unity3D. Using the Meta 2 users could see and hear an augmented holographic virtual coach in the room. The Kinect 2 was used to capture the user's motions. Kinect Visual Gesture builder software [4] was used to capture the correct performance of the exercises during the development phase and stored the data in a database. This database was later used to compare the live performance of the exercises by the users with the correct stored gestures in the database and to provide proper feedback in real time to them. Upon correct detection of the exercise performance, users received auditory feedback (e.g., "Well done") from the virtual coach. In addition, we modeled five different virtual coaches: One realistic male (see Figure 1 (b)), one realistic female (Figure 2 (b)), and two cartoony characters in both genders (Figure 2 (c) and (d)) were designed and implemented using Adobe Fuse CC software [1] and animated using Mixamo [3]. Each virtual coach had its own voice generated using an online Text-to-Speech service [2]. The fifth virtual coach was a realistic polygonal 3D reconstruction of a real person (Figure 2 (e)) which was created using the RGB and Depth cameras of a Kinect 2. The holographic representation of a medical doctor offline could then be sent to all her/his patients without being physically present. This avatar design allows the clinicians to change the offline mode into an online telepresence system upon request. This way, using two Kinects, one at the patient's home and one at the clinician's site we will be able to create a telepresence system [13].

4 Evaluation by Patients

In order to evaluate the first version of our prototype and gather user preferences, we performed two focus groups with older adults in London. The participants of both focus groups were given a consent form, which they read and signed.

4.1 First Focus Group

The first focus group had 5 participants (3 female) with an average age of 74.8 years old (sd = 6.14). 60% of the participants did not have a balance disorder and 80% did not have prior experience with HMDs. All participants wore the Meta 2 HMD and saw all five virtual coaches demonstrating selected exercises to them. They also performed one exercise: standing and bending over as if to pick up an object off the floor, and received feedback from the virtual coach. Following that, they answered our questions and questionnaires.

(a) A user wearing the HMD receives instructions from a virtual coach. (b) Virtual coach demonstrates correct performance of an exercise.

Figure 1: Example of the system in use

The first questionnaire was a modified version of the System Usability Scale (SUS) [7] questionnaire. The average SUS score was calculated as 72.5 (above average).

The second questionnaire was a modified version of the *Co-Presence and Social Presence in Virtual Environments* questionnaire [15] which has 15 statements to measure four sub-dimensions of social presence using five-point Likert scales (1=strongly disagree - 5=strongly agree). See Figure 3 for the results. In addition, we asked them to rate different avatars for the virtual coach on a scale of 1 (very bad) to 5 (very good). The results can be seen in Figure 4. Moreover there was another question about their virtual coach preference. 60% of the participants preferred the realistic male virtual coach. The score for the naturalness of virtual coach movement was 3.4/5.0 (5 means really good) and the score for the naturalness of the virtual coach speech was 3.8/5.0 (5 means really good).

Finally we received many comments from the participants from which we could extract the following user suggestions: Addition of volume control for the virtual coach voice, a lighter and smaller HMD (one participant showed his sport-glasses with a cord hanging from the neck to protect them from falling or get lost), make the virtual coach more responsive, provide more feedback and more interaction, less instruction from the coach with more dialogue and conversation, UK English accent would be preferred, should not be a generic experience, should be more adaptive on a patient basis, virtual coach mood should look more optimistic and happy (not grumpy), clear and colourful clothes for the virtual coach, a progress feedback on a daily basis, and detection of safety by the system.

4.2 Second Focus Group

47 people participated in our second focus group. Due to time limitations it was not possible for all participants to use the system. Therefore, we demonstrated the system to them and used a ques-

(a) Realistic male (b) Realistic Female (c) Cartoony Female (d) Cartoony Male (e) Realistic polygonal 3D reconstruction

Figure 2: Variations of the virtual coach

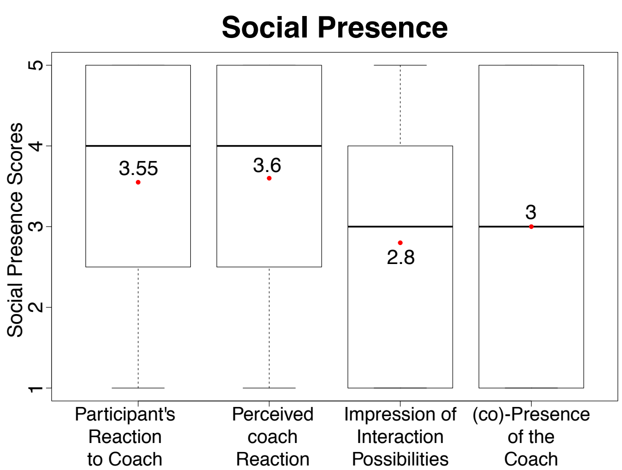

Figure 3: Social Presence Scores

Table 1: Exercise space available at home.

Percentage of participants	Space
17%	$\leq 1m^2$
33%	$2m^2$
24%	$3m^2$
26%	$> 3m^2$

tionnaire to gather their opinion. The following sections are a summary of our analysis on the questionnaires.

4.2.1 Demographic

Age: the minimum age of the participants was 60, maximum 84, and average 73.61 years.

Gender: 29 females (63%) and 17 males (37%).

Balance Disorder: we ask the participants whether they suffer from a balance disorder or not. 13 answered with Yes (28%), 20 with No (42%) and 14 with Maybe (30%).

Falls: We also solicited information about the number of falls and near falls during the last 6 months. A definition for each term was provided: a fall is an event that results in a person coming to rest inadvertently on the ground or floor or other lower level. Whereas a near fall is an event in which a person feels a fall is imminent but avoids it by compensatory action, such as grabbing a nearby object or controlling the fall. They reported a minimum 0 for both types of falls, maximum 14 falls and 24 near falls and in average 1.065 falls (sd = 2.27) and 3.256 (sd = 4.83) near falls.

Exercise Frequency: 81% of participants perform daily exercises (81% daily, 15% weekly, 4% never) this includes physical activities such as gardening etc.

Computer Usage Frequency (including smart phones, iPad, tablet, etc.): Most of our participants use computers daily (94% daily, 4% weekly, 2% never).

Confidence in using technologies: In a range of 1 (very bad) to 5 (very good), the average rated their confidence 3 (sd = 0.91).

Broadband: 94% of participants claimed that they do have broadband at home.

Contact Medical Doctor: We asked about participant's means of communication with their medical doctors. Participants chose: Telephone: 89%, Mobile phone: 37%, Email: 38%, SMS/text message: 11%, Instant messengers (e.g., WhatsApp): 8%, Social Media: 6%, Other: "Through online appointment system" , "almost impossible to contact", and "increasingly difficult to make an appointment".

Free Space at Home: A quick look at Table 1 reveals that participants have limited space at home.

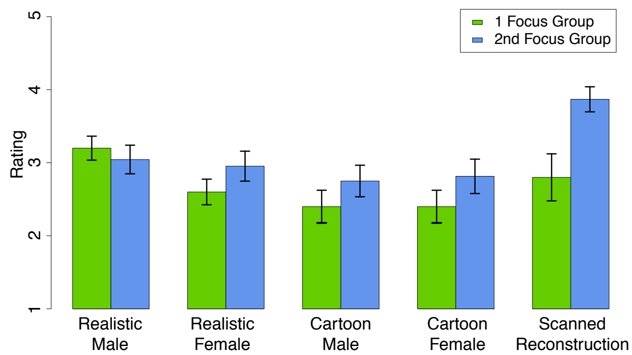

Figure 4: Virtual coaches' ratings with Std. Error.

4.2.2 Evaluation of the Virtual Coach

Following demographics, we asked participants if they would prefer to see a medical doctor in the form of a hologram if it meant that they did not have to wait for weeks for an appointment. (41%) of the participants answered this question with *Yes*, 32% answered with *No*, and 27% answered with *maybe*. We then asked them to rate the different avatars of the virtual coach (Figure 2) on a scale of 1 (very bad) to 5 (very good). We projected different avatars demonstrating an exercise on a screen. Due to a technical problem the 3D reconstructed avatar (Figure 2e) could not be displayed live. Instead we displayed a static image and elaborated on the idea to create a holographic representation of a physician which can be sent to all his/her patients without being physically present. The results can be seen in Figure 4. Following that we asked participants to choose their preferred virtual coach avatars (they were free to make multiple choices). Based on their responses, 53.3% preferred the Realistic 3D reconstruction of a real human, 28.8% the Realistic Female, 24.4% the Realistic Male, 11.1% the Cartoon Female, and 4.4% the Cartoon Female. They also rated the movements of the virtual coach in average by 2.82 (sd = 0.98) and the sound of his voice as 2.88 (sd = 1.11) out of 5. In addition, we received some feedback regarding the movement as "[It] need[s] greater detail and positioning for safety". Other comments about the voice were "speech needs to be quite clear syllables, well-articulated, as older people "decode" fast speech rather badly quite often; for the male Dr, very good and clear", "for me realistic woman model sounded best", "too fast, important words wrongly stressed, computerized speech is ok, but it must follow natural English rhythm", "need slower speech".

In the next question we asked them what they would like to personalize for the virtual coach. The results were as following:

- **Gender**: 48% (22 people)
- **Clothes**:28% (13 people), comments: "prefer a white lady in a skirt"
- **Colour of the clothes**: 24% (11 people), comments: "I would like to have a real[istic] coach plus exercise clothes"
- **Voice**: 61% (28 people), comments: "Instructions should be given slower", "change the volume", " the virtual coach should have a clear voice", "voice most important [to be able to change]", "speech to clarify something", voice too fast, indistinct; poor quality written language", "Volume and voice", "natural voice"
- **Age**: 41% (19 people), comments: "the virtual coach should be old", "age 35+, looking "mature" / knowledgeable", "older person"
- **Size**: 26% (12 people), comments: "The coaches are TOO thin!!", "not stick thin"
- **Nothing**: 15% (7 people)
- **Other**: In this section the participants were free to write any other characteristics which were not listed in this question. The followings are their categorized responses:

  - "**Ethnicity**": "Ethnicity", "Ethnic Group", "use people of different colour of skins"

  - **Personalization**: "I suppose to avoid boredom in the long term, personalization would be good", "like to be able to adjust", "[I'd like to personalize the virtual coach] if possible – not a big deal!"

61% of the participants selected the Voice as the property of the virtual coach that needs to be improved the most. After that is the Gender with 48% and then Age with 41% of the votes. We also included a question specifically regarding the type of the preferred voice. The majority (95.6%) of the participants chose "Natural human voice" among the other options (i.,e., computer generated or own personal physician's voice) and added some extra comments such as "can we personalize with a familiar family member voice", "don't mind as long as it is clear", "needs to be a "native English speaker", "a second language speaker – however "good" their English is not the same!!", "with an English intonation + stresses". We also asked about the preferred size of the virtual coach and 66.6% selected "An average human size" and 20% selected the "Depends on space in the room" option. The rest voted for smaller (8.8%) and bigger (4.4%) than an average human size. They also provided us with some comments such as "would get to know preferred size after use", "as long as the whole person is in the frame", "just large enough to make the specific exercise clear", "would like to adjust".

The following section inquired about the interaction with the virtual coach. More than half of the participants (56%, 26 votes) stated that they would like to interact with the virtual coach via speech. After that they voted for body gesture with 17 votes (33%), real physical touchpad with 11 votes (24%) and virtual touchpad with 8 votes, 17%. Finally, 24% of the people stated that they would not want to have interactions with the virtual coach at all. Participants also asked for voice commands such as "Repeat: speech interaction telling virtual coach to repeat the exercise", "to repeat instructions for example", "I would like REPEAT ACTION", "to trigger repetition", "repeat if required", "might want to repeat", "touchpad if speech/movement does not work", "this is all down to how fast the response mechanism is", "to have a choice depending on exercises and how you manage". Therefore, the ability to trigger the "repetition of the instructions" is the most desired function among the interaction comments. In addition, we asked about the preferred distance to the virtual coach, which 57.4% of them selected 2-3 meters (or approximately 6-10 feet) and 42.5% selected 1-2 meters (or approximately 3-6 feet).

Finally we gave them a modified version of the SUS questionnaire which had 5 questions regarding the usability aspects of the prototype. Q1-Q2 and Q4-Q5 of this questionnaire could be answered on a scale of 1 to 5 representing a range of Strongly Disagree to Strongly Agree with the statement of the question. Q3 (the assistance question) was a multiple choice question investigating probable types of assistance for using the system. The results of this questionnaire are as follows:

- Q1: I would like to use this system frequently if it meant that it would reduce my risk of falling. A: mean=4.15, sd=1.02
- Q2: I think this system would be easy to use. A: mean=3.69, sd=0.99

- Q3: I think that I would need assistance to be able to use this system. If yes, what type?

  - No Assistance: 41% (19 votes)

  - Physical Assistance: 11% (5 votes)

  - Technical Assistance: 39% (18 votes), comments: "Technical assistance to start with"

  - Educational Assistance: 17% (8 votes), comments: "at start to confirm I am using correctly"

  - Medical Assistance: 6% (3 votes)

- Q4: I would imagine that most people would learn to use this system very quickly. A: mean=3.04, sd=1.03, comments: "difficulty very often increases with age, regardless of education", "need a trainer for 1st try"

- Q5: I would feel very confident using this system. A: mean=3.67, sd=0.87

We also received some comments such as "Might need to have a chair to set up", "instruction to sit", "sitting would be good".

In brief, the participants found the system easy to use, easy to learn, and felt confident to use it. 41% of the participants stated that they need no assistance to use the system or only technical assistance (39%) and mostly at the start of using the system. Based on their opinion, they highly agree to use the system if it meant that it would reduce their risk of falling.

4.2.3 Additional Comments

The closing questions of the questionnaire were three open questions to gather the participants overall opinion about the project. Therefore, we asked them what (if anything) would they like to change about this system. The followings are some selected responses:

- "I think the idea is good and could reach some people. The motivation issue is probably the most difficult thing to solve. This could be very interesting."

- "I would like this to be extended to a group use … eventually… I this this is a great preventative idea."

- "I would be keen to have headset + sensors as compact + neat as possible, to take up least space. I would like the system to be easy to clean + maintain"

- "At present I do 15 mins of SBX exercises on nearly all days. This might motivate me – would have to try. Have not fallen yet – but always try to hold on to banisters etc. on stairs (age 81)"

- "Headset too heavy now; virtual coach needs to be a normal size and look friendly/helpful"

We also asked them whether they would recommend the system to someone else. 54% answered this question with Yes, 41% with Maybe, only 5% with No.

The last question gave the participants this opportunity to give us any further comments. The following are some selected comments:

- "This should not be a substitute for face-to-face contact and group advice, it might help those people who are isolated but we are social beings and this should be encouraged"

- "reduce size of equipment, tailor it to old people, people with disabilities, special needs; good luck"

- "I would recommend it to my locality NHS groups and Pensioners Forum for information on future developments and improvements of older people's falls- a major NHS cost for subsequent treatments and death."

- "If this has to be GP recommended I think the GP should set the standards to start. This system does not allow for health conditions that vary from day to day. One and the most common falls are around steps, but not mentored on this programme. The looking down when walking outside home is very necessary because of uneven pavements which tip balance and lead to falls, and differs from training inside house. The constant use of screens, trigger migraine and vertigo attacks as well as epileptic episodes."

5 Conclusion

Following the NICE guidelines for fall prevention and UCD approach, we developed a prototype for training balance exercises at home. In order to gather user preferences and acceptance, we performed two focus groups with older adults. Results suggest that participants generally liked the idea but thought the implementation has room for improvement. They specifically requested a lighter and less bulky HMD. Questionnaires reveal that elderly people are displeased with the waiting times for making an appointment with a real physician and as a result of that they welcome such a personalized exercise coach system (section 4.2.2). Personalizing the coach seemed to be especially important to the participants and they mentioned they would like the coach to be more friendly rather than a neutral expression and have a more natural sounding voice. Moreover, they wished to be able to change, among other attributes, its gender, ethnicity, and age (e.g., to make the avatar look more authoritative). Speech control and the ability to trigger the repetition of the instructions were the most desired functions among the interaction comments.

The realistic polygonal 3D reconstruction of a real person was rated as the most pleasant virtual coach to work with in the second focus group when it was presented as a concept, but not as an actual implementation. This suggests that the recorded avatar needs to be of high quality to be accepted as representation of a real physician.

In addition to this, demographics suggest that elderly people's homes have limited space for exercises, so designers should take that into consideration when designing the exercise program. Among with the other findings from our focus group these results should be used by interactive coach system designers to improve their systems and make them accessible to patients.

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