Exergames in Augmented Reality for Older Adults with Hypertension: A Qualitative Study Exploring User Requirements

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Abstract. The development of Augmented Reality head-mounted displays for the commercial market offers new application possibilities in combination with exercise therapy. Patients who are medically advised to exercise regularly, such as hypertensive patients, could increase adherence through gamification elements combined with immersive projections in their real-world environment. Furthermore, different vital data could be displayed during their training. In order to determine the needs and preferences for an exergame for elderly hypertensive patients we conducted a requirements analysis through semi-structured interviews in older adults (n = 11) over 65 years with diagnosed essential hypertension. The data collected was analyzed through a summarizing content analysis. The requirements analysis revealed mandatory requirements in the areas of: overall system, hardware, software, gamification and monitoring. The results indicate that these potential users of an AR exergame, who are vulnerable target group, must be considered separately from others in terms of additional factors such as comorbidities, danger of falling or acceptance of technology.

Keywords: Augmented Reality · Rehabilitation · Hypertension · Requirements analysis · Seniors

1 Introduction

Arterial hypertension is highly prevalent among older adults and is a risk factor for developing e.g. coronary artery disease, stroke, myocardial infarction and kidney insufficiency. Studies have shown that every third adult in Germany suffers from hypertension, which affects approximately 25 million adults in total [1]. In the highest age group of 70–79 year-olds, even three out of four adults have hypertension in Germany. Along with other lifestyle modifications, physical activity is a commonly recommended non-pharmacological treatment for hypertensive patients. Guidelines of the European Society of Hypertension and the European

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Society of Cardiology suggest performing moderate–intensity dynamic aerobic exercise 5–7 days per week to reduce blood pressure [2]. In the longer term, only regularly performed workouts seem to be effective for hypertensive patients. However, the continuity of practice can be an obstacle for many older adults. Since it is hard to motivate oneself for daily exercises, exergames developed specially for the target group could increase the motivation of elderly users. By utilizing gamification elements, it might be possible to promote long-term usage of the system and thus a higher training frequency.

Previous studies have shown that Augmented Reality (AR) exergames are motivating during therapy and suitable for in-home rehabilitation, what has already been shown in existing studies with a Microsoft Kinect System [3,4]. The study by Hino et al. [5] did find out that the number of step in their sample of middle-aged and elderly players was higher than in non-players until 7 months after the release of PokémonGo. With the development of Augmented Reality (AR) head-mounted displays (HMD) for the commercial market, such as the Microsoft HoloLens or the Magic Leap One, the use of AR in combination with exercise therapy offers new opportunities. In addition to increasing adherence of the patients through gamification techniques combined with immersive projections in their real-world environment, it is also possible to display assistive health parameters during exercises in AR exergames. Hypertension patients could benefit from this new technology, which is interactive, adaptable to individual needs and applicable at home.

Our study was carried out as part of the BewARe project, which aims to develop technically assisted movement training for seniors with hypertension, based on an intelligent augmented reality system consisting of an augmented reality application and various sensors. The BewARe project is a joint project financed by the German Federal Ministry of Education and Research (BMBF). The project lasts three years and began in August 2018.

2 Methods

The purpose of this qualitative study was to determine the requirements for a sensor-assisted exergame in an AR system for elderly hypertensive patients. A requirements analysis was carried out to ascertain the requirements. In the course of identifying the requirements, we conducted semi-structured interviews with seniors over 65 years. The interviews were held in German; the quotations used in this paper were translated.

2.1 Procedure

In a telephone call, interested seniors were first informed about the study and if they agreed were subsequently interviewed about the inclusion and exclusion criteria in a screening. Before the interviews, the corresponding screening assessments were carried out on site. The fall risk was tested by the Tinetti Test [6] and cognitive impairments was measured using the Mini Mental State Examination

(MMSE) [7]. The semi-structured interviews included 11 subjects and consisted of three parts: a first part for personal/non-technical requirements, a second in which the subjects tested a user experience demo in a VR and AR environment, and a third part concerning individual requirements for an AR system. The interview guideline created by the Geriatrics Research Group included the following main content categories: dealing with hypertension, forms of exercise in the past and today, technology usage, monitoring of health data, general requirements for an AR movement training, hardware and software requirements, requirements for motivational elements and requirements for safety aspects. The ethics committee of the Charité – Universitätsmedizin Berlin approved the study (no.: EA2/212/18).

2.2 Participants

Semi-structured interviews were conducted with 11 elderly adults diagnosed with essential hypertension (Stage 1). The sample consisted of 6 women and 5 men with an age range from 65 to 91 (mean 73.09, SD 7.53). The subjects included had no increased danger of falling (Tinetti Test: 27.91, SD 0.302), had no cognitive impairments (MMSE: 28.91, SD 1.221) and their hypertension was drug-adjusted. The results of the MMSE between 24 and 30 were interpreted as no cognitive impairment. A score in the Tinetti Test in the range of 19–24 points indicates a risk of fall. All of the examined subjects had low risk of falling ($\geq$24 = low risk of fall).

2.3 Materials

Exergame Prototypes. Exergame prototypes were used to create a common understanding for AR and VR among older adults. Due to the lack of prior experience in the living environment of older people, it cannot be assumed that every senior knows how the VR and AR environments differ. For this reason three different user experience prototypes were used, two in VR and one in AR.

The first exercise variation was in a standing position and involves a squat in the VR environment. During the task the user can see an animation model similar to a mannequin that replicates his or her movements. When the users hands are stretched forward with the controllers, a large dumbbell appears. The user has to perform the squats in the defined execution area. The control of the exercise execution is graphically represented by a transparent cylinder. If the exercise is carried out correctly, the dumbbell turns green. The instructions were presented as text in the game.

The second exercise variation was conducted in a sitting position and involved a seated trunk rotation, also in the VR environment. In this prototype a transparent bar appears in front of the user. The user moves the controllers through this preset path. If the exercise is performed correctly, the displayed grips will turn green. The user sees, as in the first exercise, a figure who simultaneously turns with his or her movements. The instructions in this prototype were presented by a speaker.

The third exercise variation was similar to the first, although an AR environment was used instead of a VR environment. The users are in a standing position and see their real environment and a virtual figure that appears in the space in front of them. The instructions were presented as text in the game. The user is asked to perform squats. While performing, the user sees a simultaneous movement of the figure and of a green dot.

Fig. 1. Task-based part in VR.

Fig. 2. Task-based part in AR.

HMDs for the Prototypes Used. In the task-based part two different HMDs were used in order to show the differences between a VR and AR experience (see Figs. 1 and 2). As VR headset we used a HTC Vive [8] with two stationary reference units, which were tracking the users headset and controllers in space. As AR headset the HoloLens [9] was used, which has its own native tracking system built into the HMD.

2.4 Data Analysis

All interviews were recorded and transcribed using the transcription software f4. A summarizing content analysis by Mayring [10] was carried out with the data analysis program ATLAS.ti 8. The aim of the content analysis is to reduce the material and to create an overview through abstractions. The analysis contains among other things paraphrasing, generalization to abstraction level and reduction of data units. The example given in Table 1 shows the process of clustering in the analysis using the example of category: education of the system.

Table 1. Procedure example of the summarizing content analysis within a category.

Case	Quote	Paraphrase	Generalization	Reduction
4	"You can read it through beforehand, but it's like any other instruction manual, you don't understand it anyway"	Read beforehand, like any other manual - you don't understand it	Manuals not understand-able for the peer group	**Education of the system:** The system should not be learned via a manual
5	"So the best thing is, if you have it while you have the glasses on, then you get it explained somewhere here in the program"	Explanation in the program while wearing glasses	Tutorial	The system should be learned by a tutorial in the game
9	"I don't think I'd like to read a manual so much, so the best thing is if you get it explained somewhere in the program while you're wearing the glasses, or if someone explains it to you but then not with the glasses on. Reading a manual before or something like that, I wouldn't find that very helpful"	Reading a manual is not very helpful, explanation in the program or by someone	~~No manual~~, ~~tutorial~~, personal assistance	The system should be learned by personal assistance

The first step was to determine that parts of a single sentence, entire sentences and entire paragraphs could be used as analysis units. Subsequently (step 2) we paraphrased the 803 content-bearing passages. In the third step we determined the envisaged level of abstraction and a generalization of the paraphrases was conducted. In step 4 a first reduction was done through the selection of semantically identical paraphrases. The paraphrases with the same meaning were deleted. The second reduction (step 5) merged paraphrases to the envisaged level of abstraction. In the sixth step we compiled the new statements as a category system. Finally we compared the statements to the source documents. Table 1 shows an exemplary process that was carried out within the framework of the study.

All relevant data units (quotations) were assigned manually to specially drafted coding rules. Two scientists independently analyzed the 11 documents using the four-eyes principle. The coded quotations were grouped into semantic domains and an inter-rater reliability according to Krippendorff was calculated with Atlas.ti 8 for each domain along with the overall concordance degree among the raters.

3 Results

The following paragraphs describe the main results for individual technical requirements (e.g. hardware, software) and non-technical requirements (e.g. motivational concepts, application possibilities) for an exergame in AR. The results presented in the next subsections are organized into the following semantic domains: overall system, hardware, software, gamification and monitoring.

3.1 Overall System

The requirements of the overall system gathered during the interviews are presented here. The interviews with hypertensive seniors revealed concerns about the application of a VR systems. The non-existent perception of the real environment is seen as a factor that increases the risk of falls. *"The other thing about stumbling is of course interesting, so you would have to, let's say, I would use such a device [VR] in the apartment, i.e. I would have to somehow think about it first, that there is nothing I could trip over and that I also have to think about that I can't bump into anything." (Subject03, female, 70 years old).* The recognition of the dangers in the room makes the application of the AR system in comparison to a VR system for elderly users more universally adaptable in different locations e.g. in their domestic environment. Since the domestic environment was the most frequently indicated setting of use, elderly users should be able to recognize the dangers in the room and thus the AR system enables the users a more secure usage.

In addition to the question of the setting, an important decision for the development of an exergame was the type of game. Many of the hypertensive seniors have already been active in sport clubs for years or are active in cardiac rehab groups. For the seniors these groups play an important role in their social participation and offer social support from which friendships emerge. *"So with this swim group, they're steady girlfriends, you can see that clearly." (S11, female, 78y).* Some interviewees worried that if the subjects were to use an AR exergame they would miss the interaction with others. Therefore, some subjects require that the system should include a multiplayer mode.

Another important aspect is the operation of the system. Especially with the task-based part it became clear that controlling the demo with gesture control was more difficult for the subjects than with a controller. For some, gesture control caused frustration. *"I'm always under so much pressure when I think I didn't get it right away." (S03, female, 70y).* The operation with a controller felt more natural to many. Other test persons said that the correct gesture execution is very practice-dependent and not directly understandable the first time. *"So, once I really understand it, it's easy too. But the other one [controller] is of course even easier." (S11, female, 78y).*

In order to test the homogeneity of the coders in this semantic domain about the overall system, an inter-coder reliability was computed with Krippendorff cu α, which was 0.968.

3.2 Hardware

The hardware requirements of the interviewed subjects are described below. Many of their responses regarding the hardware focused on the effects on their safety. Almost all seniors considered a cable to be an unnecessary tripping risk. *"I do not know, I personally always find the easier it is, the better and [...] whenever there is so much there and there, I find it easier without a cable" (S02, female, 71y)*. The transparent display of the HoloLens allowed the seniors to perceive their surroundings, which was seen as very important. *"That's the way it is, if you turn back and forth a few times or walk [in VR], you lose a bit of the overview. That's normal, I think." (S04, male, 71y)*. The subjects also expressed the desire that the headset should be easy to put on and take off. In addition the headset should be lighter than the headsets demonstrated.

The Krippendorff's cu α was calculated for the semantic domain at 0.981.

3.3 Software

This subsection describes the main requirements for the software of the exergame in detail. The interviews identified two groups of potential users of the software: Users with low intrinsic motivation and users with high intrinsic motivation. The statements of these two groups on the environments they could imagine being displayed in AR were related to their self-determination. The users with a high intrinsic motivation did not want an illusory environment; instead they preferred the real environment with additional vital data or the explanation of the execution of the exercise. *"The pure practicality, that would be more to me" (S04, male, 71y)*. The users with a low intrinsic motivation or the users who needed an extrinsic motivation wanted environments that are illusory and allow the user to experience and get motivated by a different place through immersion. *"So I could go for a walk in the mountains, even though I'm walking around on the carpet at home." (S03, female, 70y)*. In terms of the exergame environment, these users mentioned natural environments in the game such as forests, mountains and meadows. Figure 3 shows a sample network of two desired environments and the relations to the motivation of the subjects. Some subjects who wanted to perform ADLs in the illusory environment expressed an additional requirement for the environment: *"I know, light gardening, [...] raking or something like that" (S06, female, 66y)*.

Subjects could learn the system in a variety of ways. Many of the subjects do not want to learn the system through a manual. The seniors preferred a video sequence, a tutorial or personal operating instructions instead. *"If that were possible, yes. That one then says:'Now you have to do faster' [...] or adjust your field of view more precisely and therefore a voice control in the background that draws attention to the errors. Yes. Or which reads out the manual and then errors can be corrected immediately by the respondent or me then, in that case." (S09, male, 71y)*.

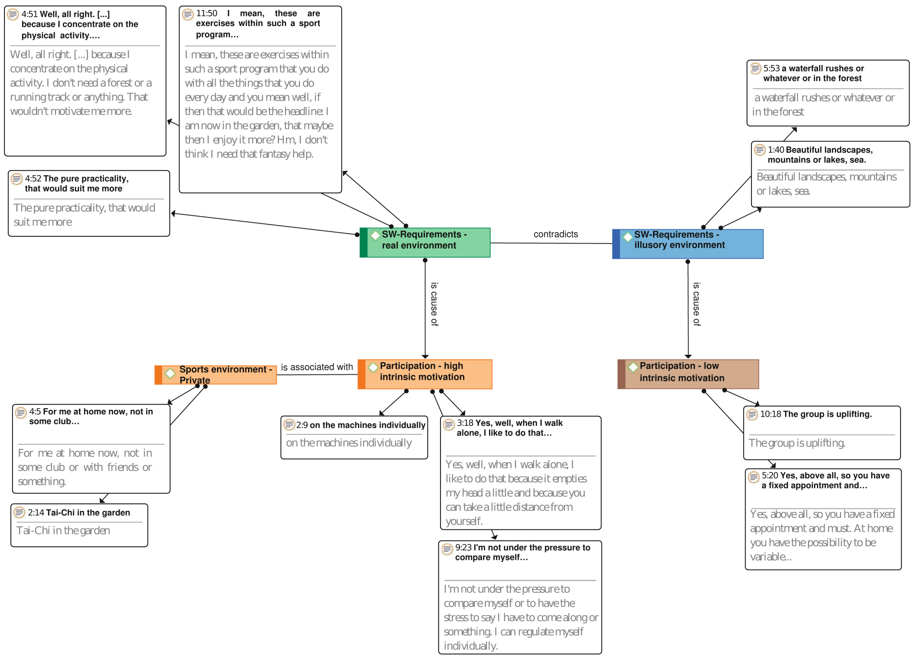

Fig. 3. Atlas.ti network view of the desired game environments.

The inter-coder reliability, computed with the Krippendorff cu α was on this semantic domain 0.970.

3.4 Gamification

The following subsection describes the main requirements of the game mechanics for a potential augmented reality exergame based on the conducted interviews. Many of the seniors wanted as progression feedback a comparison with their own previous data rather than a comparison against other players. This allows the user to compete with his or her own performance, which increases motivation and allows the subjects to monitor their own progress. This type of data monitoring makes it possible to detect progress e.g. through a decreasing heart rate or blood pressure during training. *"So I would consider a comparison to past times or periods of data in relation to the data, which are then detected. Now, as I said, I write this down and then I watch how it has developed. I could also imagine that it could be implemented graphically."(S09, male, 71y)*. However, the subjects indicated that the data should only be available afterwards, not while they conduct in-game activities, because that would distract them. Furthermore, the target of the exercises in an exergame should be individually adaptable and individual training load benchmarks should be considered. *"Yes, yes! Maybe it's a target setting, it's not 3 squats, but 10 and at some point it has to be 15 and maybe 20 and then at some point it's over again. Well, I don't want to go to the*

Olympics. I want to be 100 years old, but I don't have to go to the Olympics." (S01, male, 81y). For an individual adjustment of the goals, the current fitness status of the users should be essential in an AR exergame.

The story telling in the game was also perceived as an important element. Since video game experience could not be assumed in the sample, movies were used to classify the game genre and the story line. The seniors interviewed mentioned historical movies ten times as movie preferences, crime films five times, political television content four times, nature movies twice and action movies once. As a narrative story in the game, most could also imagine historical actions, as they indicated in their movie preferences. *"Something historical, for example on the basis of a uh yes of a fate basically, so that one says yes that interests you, how does that go on, how has he or she mastered that in his or her life. Basically it is, of course, a primitive crime thriller." (S11, female, 78y).* It was interesting that many subjects experienced the Second World War or its consequences, for this reason a war scenario would be unthinkable for the target group. "*For example, I don't want to be involved in any theatres of war here. I also don't want to drive a tank and as many games today, as I said I have no game, but what you get or what you see, as I said I dont want to be involved." (S10, male, 69y).* Moreover, the Bartle Test of Gamer Psychology [11] was applied in order to find out possible player types of the target group based on Bartles taxonomy. The Bartle Test of Gamer Psychology showed that 8 seniors can be classified as explorers and 3 as socializers in a gaming scenario. Figure 4 shows a radar chart of the average scoring of the subjects in the four categories, each of which can be rated up to 100%. Both player types, socializers and explorers, are interested in interacting. For socializers the interaction with other players is the focus of the game. For explorers the interaction with the virtual world plays a decisive role. While the explorers enjoy discovering new worlds and details of game mechanics, the socializers are interested in connecting with other players and want to get involved in the community. The results met our expectations from the interviews, as many stated that they greatly appreciated the group dynamics.

The Krippendorff cu α for the semantic domain was 0.989.

3.5 Monitoring

This subsection shows the main monitoring requirements of the seniors. The subjects indicated that they consider it important to control their blood pressure and heart rate. *"Oh no I mean my blood pressure, pulse and so on, if it is not somehow such a giant apparatus, but some small device I could quite well imagine that." (S01, male, 81y).* The wish was expressed for a kind of training history with various health determinants to be displayed in order to achieve progress. However, the data should not be displayed during the game. *"And during the exercise you would get distracted and feel disturbed [by vital data]." (S05, female, 71y).* It would be most pleasant for the test persons if the heart rate could be recorded via a wristband, e.g. via a smartwatch. This wearable should also be usable in their everyday life beyond the training.

The Krippendorff cu α for the semantic domain was 0.968.

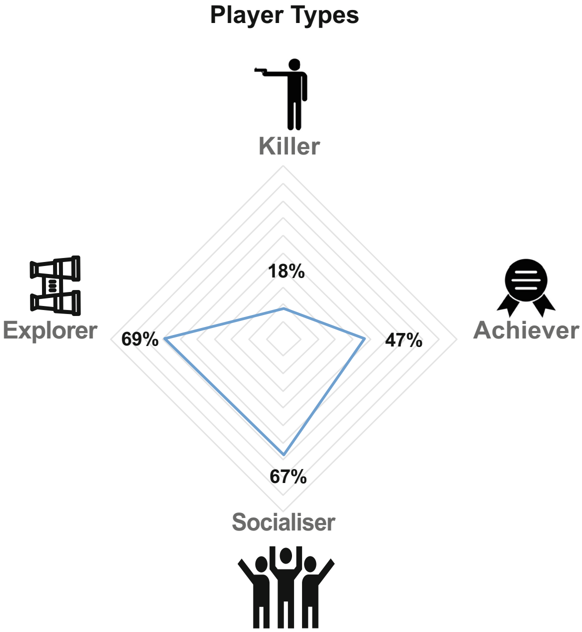

Fig. 4. Radar chart of the rounded average scoring of the subjects for the four player types according to Bartle's taxonomy. Each category can be rated up to 100%. The responses represent a total of 200% distributed across the four categories.

4 Discussion

The aim of the study was to determine the user requirements for a sensor-assisted exergame in an AR system in elderly hypertensive patients. We performed a requirements analysis through a qualitative analysis of semi-structured interviews with hypertensive seniors in order to gather mandatory requirements.

The results indicated that many seniors would prefer an AR system to a VR system because of the lower risk of falling, which is based on the visibility of the environment and the wireless nature of the AR HMD. However, the AR system should not be controlled through gestures and or if so, it must be practiced personally beforehand with the older users, whereby the technical socialization of the generation and of the individual in his or her personal history must be taken into account. Optionally, the Hololens clickers, which interact with holograms, could be used and further explored. The subjects also stated that the headset should be easy to put on and take off and be lighter than the headsets used in our study, which were 579 g.

The results presented under software requirements show that involving seniors in the development of an AR exergame is advisable to increase the successful adherence of this user group. The requirements analysis offered insights about the game type to be developed. The findings demonstrated that the desirable game type is connected with the motivation of the seniors. Hypertensive seniors who already have a strong intrinsic motivation need more of an assistive AR exergame that helps them with the vital data documentation. Hypertensive seniors with a weak intrinsic motivation, on the other hand, would like to immerse themselves in other worlds and play an exergame together with other seniors. The interviews indicated that for some seniors, groups are an important facilitator in their habit formation. Previous research showed that a portion of the elderly prefer home-based exercises [12,13]. In their position paper Brox et al. [14] have pointed out that social interactions are an important factor in exergaming. The results of our qualitative study underline and connect these opinions by showing that seniors have a strong desire to interact socially even in the exergame, which however could still be performed at home. Modern technology opens up new opportunities that should be further researched; e.g. through online multiplayer modes in the AR, through meetings of interest groups for a collective AR exergame, or through simulated groups with avatars, it might be possible to contribute to social interaction during the game and thus increase of the motivation of older users for training adherence with exergames. First studies have shown that playing AR exergames with an HMD in a multiplayer mode can be combined with the goal achievement of physical exercises [15] and enjoyable for people of every age group [16]. Attig et al. [17] showed in their study that there is a strong dependency effect in users with high extrinsic motivation for tracker usage during physical activity, which should be also considered in developing an AR exergame. Thus, even if the exergame promotes social interaction, it should also intrinsically motivate the users.

Furthermore, our paper highlighted the main requirements for the game mechanics. During the exergame the target group don't want to see their vital data continuously, as it would distract them. This implies that the vital parameters should only appear as a result in retrospect or as a warning during the game and need to be recorded in the background. Heart rate, blood pressure and exercise time were perceived as the most important parameters. The target of the exercises should be individually adaptable and individual training load benchmarks should be taken into account. For this reason, machine learning for exercise data evaluation was integrated in the BewARe-Project. The individual adaptability plays a decisive role for the group of hypertensive patients, as some individual comorbidities lead to movement limitations or various medications reduce the load intensity of the patients, i.e. if these limitations are not respected, the AR exergame users will be exposed to a potential danger. For this reason, it is worth considering having the input parameters entered by a doctor or medical staff. The Bartle Test of Gamer Psychology used here showed that the two most frequent player types in the sample were explorers and socializers. This supports the results of the interviews, in which social interaction with other seniors in exercise was the main concern. Important conclusions can be drawn from the player types of the target group about the goals and motivations to play the future exergame.

The 130 mandatory requirements collected from the interviews will be prioritized within the consortium in the BewARe-Project according to the MoSCoW-Method. The requirements serve in the ongoing project for the conception and the use-case ideation of the exergame to be developed.

5 Conclusion

The use of modern AR HMDs during home exercises could greatly benefit elderly hypertensive patients by increasing their adherence. This target group of older adults must be considered separately from others in terms of additional factors such as comorbidities, danger of falling or acceptance of technology. The results obtained will be used to define use cases for the BewARe-Project to generate a concept for exergames.

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