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Bruun-Pedersen, Jon Ram; Pedersen, Kasper Søndergaard; Serafin, Stefania; Kofoed, Lise B.

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Augmented Exercise Biking with Virtual Environments for Elderly Users: A Preliminary Study for Retirement Home Physical Therapy

Jon Ram Bruun-Pedersen*
Aalborg University Copenhagen

Kasper Søndergaard Pedersen**
Aalborg University Copenhagen

Stefania Serafin***
Aalborg University Copenhagen

Lise Busk Kofoed****
Aalborg University Copenhagen

Abstract

Virtual reality (VR) has been shown to function well as an assistive technology to physical therapy for elderly users. Elderly users are a unique user group in this field, due to their characteristics and demands. They are also a user group that can definitely benefit from VR technology, which is unfortunately a perspective that seems elude the VR community. This study explores how augmenting a manuped exercise (chair-based exercise bike), using an interactive screen-based virtual environment (VE), can change the exercise experience for retirement home residents. It is the first study in a series of studies, initiating an investigation into how to use VR to augment conventional exercise experiences, specifically for the retirement home resident audience. In a larger scope, the ambition is long-term to use VR technology to increase motivation with retirement home residents, to uphold a regular exercise routine.

The results showed that a majority of subjects reported to support the VE augmentation and preferred the VE based exercise experience to the conventional exercise. This supports VR as an assisting technology for physical therapy, and suggests the potentiality VE augmented exercises, tailored for retirement home residents.

Keywords: Elderly, Augmentation, Exercise, Assistive Technology, Virtual Environments

Index Terms: [K.4.2: Social Issues Project]: Assistive technologies for persons with disabilities

1 Introduction

Many of us probably take our physical functionality for granted, and might not consider the central role it plays for a meaningful everyday living standard. Meanwhile, as we grow older, many biomechanical functions decay at a faster rate. Regular physical exercise will decrease the speed of such decay and allow the individual to retain physical independence for longer [1].

Physical therapy is therefore a central consideration at retirement homes. But despite daily, free access to professional physical therapy and knowledge of its clear physical benefits, many residents at retirement homes rarely or never partake in regular exercise. Meanwhile, it has been shown that VR technology has been able to work well for physical therapy in relation to rehabilitation [2] [3] [4], but most of these studies have been made with technology that, while applicable to elderly, is not designed specifically for elderly users. Retirement home residents can furthermore be considered an even more specifically demanding user group, due to their increased physical and mental limitations.

The overall question for this study is to see if a virtual reality (VR) type augmentation of the manuped exercise shows any promise as an assistive technology for the retirement home residents, and if so; which. This study attempts to a) investigate whether the elderly residents can embrace VR technology as part of their exercise experience, and b) to highlight any central parts of such experience that could be developed further in future studies. The aim for this, along with future studies, is to eventually know enough about the relationship between residents, exercise and VR, to convert the negative approach to regular exercise into an inspiring exercise experience.

2 Preliminary Evaluation

At Akaciegården, a retirement home in Frederiksberg, Denmark, a qualitative study involving 16 residents showed that the most common reason (besides body pain) to avoid exercise is laziness and lack of interest in the exercise itself. It also showed that some of the exercise routines themselves are predominantly not considered compelling or stimulating.

The exercise routine with by far the highest percentage of users at Akaciegården is the *manuped* – a regular chair-based exercise bike that uses both arms and legs to pedal (see: figure 1). It is often used, as it requires no balance and is thus considered one of the safer exercises. It is also flexible regarding the intensity of the exercise, relative to pedal resistance and pedalling speed. Especially its ability to provide low resistance exercise is important, as most residents are only barely strong enough to pedal with no resistance. For these reasons, the manuped is also one of the few exercise methods at Akaciegården that allow physical therapists to leave the residents to exercise without a need for constant supervision.

The paradox of the manuped is that while being so broadly appealing and useful as an exercise platform, it is also one of the most static and repetitive forms of exercise at Akaciegården. This paper describes the effect on the repetitive exercise experience for a group of retirement home residents, when combining the manuped exercise routine with an interactive virtual environment (VE). As previously mentioned, retirement home residents require additional considerations as a user group, as physical and mental limitations intensifies the need for a different mindset, thus suggesting a need for specific tailoring when using e.g. a VE and VR technology in general.

* jpe@create.aau.dk
**ksp@create.aau.dk
***sts@create.aau.dk
****lk@create.aau.dk

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3 Background

Elderly are not often credited for technological enthusiasm, but according to Ijsselsteijn, et al. many elderly are in fact proponents of technology. But they need reasons and purpose, and don't want unnecessary learning processes [5]. The Nintendo Wii has been given much academic attention in relation to exercise and elderly. Positive results have been shown for elderly users in relation to increased physical activity [6] and rehabilitation in relation to balance treatment [4]. As an assistive technology, de Bruin, et al. point out the usefulness of gaming elements and virtual environments (VE) in the context of elderly and exercise using the dance-mat game *Dance Dance Revolution* for balance rehabilitation [2].

Siegert and Taylor discuss rehabilitation in relation to Deci and Ryan's self-determination model [7], and how achieving intrinsic motivation with rehabilitation subjects is central. Intrinsic motivation can be described as when the reward is internally/inherently interesting to the person and brings sense of competency and self-determination. This should afford a connection between subject and its exercise routines [8].

Holden and Todorov address how VEs are able to create a connection to the users actions through feedback, which is comparable to the real world. VEs allow independent exploration, and can create associations to real world experiences, in a world that is safe [3]. Interaction with a VE can relieve the retirement home resident from certain physical challenges they might normally face in the real world, and can even serve as a distracting layer, by moving attention away from e.g. pain occurring while exercising [2].

Meanwhile, a study by Laver, et al. specifically questions the Wii as a preferable method for rehabilitation/exercise therapy, opposed to conventional physical therapy [9]. The study was aimed at hospitalized elderly patients, which is an elderly user group very relatable to retirement home residents. Results showed that subjects believed conventional therapy to be preferable and more effective. The technology was simply not physically applicable to most, and did not meet the preferences within the user group. This was to the surprise of Laver et al., who original hypothesized that the Wii Fit would be the preferred method [9].

A study performed by Deutsch et al., measure the improvements in the fitness level of post-stroke patients (N=4) while using a custom built biking simulator (the "VRACK") including a VE augmentation. The VE uses a screen to display a 3rd person avatar biking along a non-playable character (NPC). The NPC is placed to inspire the user to increase the pace, depending on the heart rate of the user. Results showed significant increases in fitness levels over an eight-week training period [10].

The above-mentioned literature provides insight into the use of games and VR for rehabilitation purposes for elderly and medical patients, and the results are promising. Studies for overall digital interaction concerns, when designing for elderly, also provide insight [5]. Meanwhile, literature is sparse on the specific considerations (e.g. content and form), when it comes to tailoring inherently interesting digital or VR experiences for the elderly - a point that was also highlighted by Laver et al. [9]. Many rehabilitation studies that support VE augmented exercise focus on the physical effect of the VE augmentation, such as how Deutsch et al. show how their VE augmentation effectively increases the users' fitness level, but does not (in this specific study, at least) why it works [10].

4 Manuped augmentation for retirement home residents

VE augmented exercise could prove an interesting alternative to conventional exercise for retirement home residents. The limitations to their physical and mental capabilities can narrow their means to travel or otherwise experience new places, and result in a confined daily lifestyle. Using VE augmentations to aid the problem of exercise motivation might therefore fit this user group. VEs have the potential to provide a fraction of an experience, which is otherwise, mostly, no longer possible.

A manuped/VE system was designed for implementation and placement in the physical therapy department at Akaciegården retirement home, to discover if resident users would embrace the technology and why they would possibly enjoy a manuped exercise with VE augmentation.

Exercise platform. As previously described, the manuped was chosen as the platform of choice, due to its flexible exercise intensities, safety in use, but also repetitive exercise nature. The manuped is shown to the left in Figure 1. The platforms on the ground have a rubber surface, to keep e.g. a wheel chair in place when locked, during the exercise. Both arms and legs can be used to pedal.

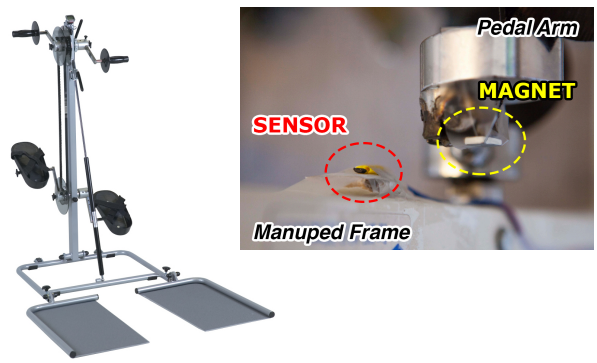

Figure 1: Left - the manuped. Upper right - the sensor on the frame and the magnet on the pedal arm.

Hardware. To track the user actions, a magnet and sensor was installed on respectively the pedal arm and frame of the manuped (see Figure 2, on the right hand side). The sensor was connected to an Arduino board and Macbook Pro via USB. The signal was processed through Max/MSP, which checked for signal changes every millisecond. The VE was displayed on a 1080p 46' Samsung LED monitor, running a relatively steady 40-50fps. The soundscape was played through a pair of Sennheiser HD600 headphones.

VE design and construction. An environment was created in Unity3d (see figure 2). Its specific environment and content direction was chosen on the basis of a qualitative study with 6 retirement home residents. Questions related the residents' preferences with real life environments that they had enjoyed experiencing. Results showed that a nature setting would be preferable. The VE was designed as a summer-time countryside and based on a trip along a gravel path going around a lake. Larger recognizable objects were trees, wooden houses and a large willow, along with additional smaller objects and environmental details such as grass. A simple soundscape was also added to support the visuals.

Figure 2: The VE designed for the residents. A nature experience was the central requirement.

VE interaction design. According to Smeddinck et al, interfacing and interacting with such technology needs to happen on a very simple level [11]. Initial trials at Akaciegården supported this, as simple real-time navigation with Wii Sports (bowling) proved too challenging for the residents. Laver et al. also address the importance of keeping the technology-interaction simple and relevant to the conventional exercise routines [9]. As a consequence, no additional interface interaction was added to the manuped, so the experience with the VE would correspond to their familiar motions. Just as importantly, the exercise routines given by the physical therapists would this way be maintained.
The subject would move on a fixed path through the VE. The only interactive features was the choice of acceleration (to a limited top speed) or deceleration (to a halt) along the path. A constant top driving speed was chosen to normalize the traveling experience within the VE for both weaker and stronger subjects.

Acceleration and deceleration happened in 4 seconds and top speed had a calculated estimate of 8 km/h. These values were found by internal testing, and chosen based on a subjective opinion on what values (speeds) felt calm, but progressive. Top speed would be obtained with a pedal frequency of 1 second. This choice was made as this pedal frequency was observed to be the most frequently occurring pedal frequency among residents on the conventional manuped exercise.

5 User study

Participants. A group of 15 subjects were chosen by the physical therapists, who wanted to have the subject group represent different spectra relating to physical therapy. The performance level of the chosen subjects varied, both mentally and physically, but all subjects would be able to ride the manuped well. All subjects also knew the manuped, which was important for the study, as it would allow them to compare the experience of the regular manuped exercise with that of the VE augmentation. Only 10 subjects (2 male and 8 female) participated, as the rest declined on exercise day, due to illnesses. The age-span was of 66 to 97 years, with an average age of 83 (mean = 82.9, SD = 9.1).

Method. The data was collected based on an in-situ semi-structured interview. This was chosen due to considerations of a) the possible need for assistance during the exercise as a consequence of the mental limitations of some subjects, b) the need for explorative conversation at this early stage of the study, and the sensitivity needed for the individuality of user group.

Procedure. Before the session began, subjects were instructed to exercise as usual on the manuped but that they could stop whenever they wanted to. They were also introduced to the fact that they would be able to see a landscape on the screen in front of them while they were exercising, and told that they would be asked questions while they were pedalling. Subjects were given the freedom to only ride for as long as they wanted to, as opposed to their regular physical therapy, where each subjects normally had a specific pedal cycle count required. The reason for not forcing round counts on the subjects was due to pure curiosity to the length they would go out of free will. All interviews were video recorded, for analysis of the results.

Interview guide. Interviewing retirement home residents needs patience, and not all residents are able understand or give meaningful answers to seemingly simple questions or explanation tasks. As such, the semi-interview was pre-expected to be a conversation, with some main topics to cover. The majority of the interview was performed in-situ during an exercise session with the VE setup. In-situ was chosen due to the predominance of dementia among many retirement home residents. Some questions were however asked after the exercise session, to seek perspective upon the exercise experience. The whole interview guide (in-situ plus post session questions) contained 11 items. Earlier experience with conversation and interviews with the residents showed that only very simple questions would be possible, to ensure that the residents both understand, and was able to give correct feedback - a consideration also supported by Smeddinck, et al. [11].

The general aim of the questions was to get an overview of the subjects' experience of being exposed to the VE while exercising. If they connected to the VE and why, related to considerations from Holden and Todorov [3], and if it actually made them want to come back for more exercise in this form, indicating signs of intrinsic motivation to exercise with the VE augmentation [7]. Beyond that, indications as to general pros and cons of the VE design and role were also addressed.
All items were thus designed for qualitative data, to increase the chance of useful information and chance of catching misinterpretations. Some items initially required closed yes/no answers, which would always be followed by the request of a qualitative elaboration.

Figure 3: Subject exercising using the VE augmentation

The interview searched for opinions and statements from the residents, from four overall themes. Theme 1 had three items and addressed opinions of being exposed to the VE, for example "Would this be a place you would like to visit in real life? – Why/why not?"). Theme 2 had three items and focused on details about their exercise experience, for example: "Is there anything specific about this type of bike-ride that you like?". Theme 3 had two items and related to if they felt a connection between their

exercise and the VE, for example "Do you have the sensation that it is you who is riding through this environment?". Theme 4 had three items and searched for implications about if such VE augmented exercise might increase their desire to exercise, for example "Which part of this experience should change, in order to make you want to exercise more?"

6 Results

All subjects liked the VE, describing it as beautiful, fantastic, pretty, and lovely and green, due to the wonderful views, which were also (partly) the reasons why 8 subjects wanted to visit the VE if in real life. Other reasons were that the VE created various associations to experiences in their past *"(…) this reminds me of the place that my daughter was born."* Positive experiences with the VE exercise experience were the possibility for exploration, "*Simply being able to do as you please. (…) If I didn't have this, I could bike. But this makes is wonderful",* the "*opportunity to get away*" and observing the nature. The oldest (97 year old) subject described her experience as the sensation of "*biking through a painting*". One subject, who is almost unable to transport herself in real life, outside the retirement home, stated the following "(…) *the sudden ability to go outside and have the world moving towards you, in front of you, and the ability go places I've not gone before, seeing things I never knew. This is wonderful*". Another subject described that the VE provided a sense of accomplishment that she did not have with the conventional manuped exercise.

8 subjects had the sensation that it was them selves driving through the landscape of the VE. *"Something always happens before your eyes and you feel that it is you are driving that trip yourself"*. 7 subjects believed this type of exercise could make them exercise regularly at the retirement home, and 6 subjects reported that it made them want to exercise more than usually. *"To sit in a regular gym is extremely boring and it needs to be made more interesting. This is good, and it provides a different experience"*.

Exploring the VE made the exercise less boring and provided energy and desire to keep going. *"I wanted to see what was around every corner. You got energy from watching the environment move pass you."* 4 subjects found the exercise experience to be less demanding than usual, and 3 subjects stated (while biking) that they would probably feel an eagerness to try again, once they were done exercising. 7 subjects stated that they would prefer the VE exercise to the conventional exercise. 3 preferred to circumvent it. One of these simply wanted to be left alone, to look out the window while biking and be in her own thoughts. She did not feel that this was possible with the VE. The two other subjects hated biking due to physical pain while doing so, and didn't feel that the VE made a positive difference. They generally wanted to not use the manuped altogether, if possible, and normally only exercised with the manuped, because they had agreed upon it with the physical therapists.

5 answered that the VE was perfect and no changes were needed. Meanwhile, 3 subjects stated that the content of the VE didn't catch their interest. While they could appreciate the sort of beauty, it did not have a differentiating effect on them. 2 subjects also mentioned that redundancy would probably become an issue, once the environment had lost its initial novelty.

One subject criticized what he perceived to be a lacking logical realism or function to the design of the small countryside community. *"The buildings do not tell me anything about where they belong or seem to have a functional sense. This environment is not built to be inhabited!"*. Constructive input from other subjects was that such thing (the VE) needed more things to explore, e.g. objects or places. It should feel more "alive", e.g. by including more movement of objects and elements such as trees, wind, water, etc. Objects themselves should inspire exploration and provide associations. An example of an object that drew attention was a large Willow placed in the middle of the VE, visible at most time by the lakeside. For objects the subjects remembered after the exercise, the willow was the dominant object, followed by (in order), houses, "normal" trees, the water (lake), grass, rocks, and nature in general. Suggestions to alternative environments were mostly a forest type environment or mountains like the Tour de France.

Time spent on the manuped for the VE ranged from 05m04s to 33m54s with an average of 14m29s (SD = 9m15s). The subjects drove between 243 and 1169 rounds during their participation (mean = 563, SD = 280).

7 Discussion

The main interests of this study are to investigate whether it seems that retirement home residents could embrace a VE augmented exercise, to locate any central parts of their experience with the VE augmentation that could become focus areas for future studies, and try to ascertain if such exercise experience could inspire them to exercise more. Meanwhile, the small timeframe (14 to 34 minutes) spent per subject gathering data for this preliminary study means that the results must be taken only as an indication. This type of exercise augmentation will need to be tested through longitudinal studies.

Literature suggests that in order to have elderly consider technology it needs to be perceived as purposeful. And while adding the VE augmentation has a logical connection to the exercise, this did not ensure that residents would accept it. The results indicated that the VE did provide a sense of purpose, as the traveling experience through the VE provided a sensation of accomplishment from the exercise. This indicates a new sensation of competency (intrinsic motivation), that seems to be non-present with the regular manuped exercise.

The VE augmentation was able to contribute several positive elements to the exercise experience, such as the (possibly also purpose-oriented) experience of moving while pedalling the manuped. The majority of the subjects felt that they were the ones biking in the VE, and expressed their enthusiasm about the actual sense of moving while exercising. The sensation of being able to "travel" to an unknown place was a positive contribution. Enthusiasm showed in the results by a curiosity to explore the VE. Meanwhile, it was not only the sense of moving that provided positive experiences, as subjects also stopped on occasion to embrace various views of the VE. In these cases, many expressed a sensation of beauty from the nature scene in front of them, and described their experience both from an overall impression of being in this "place", as well as mentioning many of the individual objects in the VE as part of that overall experience. This indicates that both the overall mood and impression of the VE, and the individual, specific objects played an important part of the experience for the residents.

Based on these aspects, 7 subjects stated that they wanted to continue using the VE augmentation if possible and 6 subjects stated that the augmentation would make them want to exercise more than presently. These are positive results in relation to the VE content- and form orientation of this study, specifically for this user group and show signs of intrinsic motivation factors, as the VE augmentation did seem like an inherent reward related to the exercise.

3 subjects did not like the VE augmentation and did not support it. This indicates that such implementation might not be suitable for all. One subject simply wanted to look out the window and have complete peace of mind while exercising. Meanwhile, the remaining two subjects generally hated the manuped exercise in general, so it remains inconclusive if this result speaks specifically against the VE augmentation or remains an expression of dislike towards the exercise form itself.

That 5 subjects stated that nothing should be changed leaves less material for further analysis or tests. Meanwhile, some did mention the possibility of a long-term, redundant experience, due to the small size of the VE. Given the preliminary VE design, with its limited size and complexity, a longitudinal exposure to this VE might not be able to provide a consistently satisfying experience. While e.g. the sense of moving will probably not degrade over time, other important experiences such as the curiosity to explore and the enthusiasm of e.g. beautiful views could fade in such a simple, static and small VE, as residents become more familiar over time. Possible improvements could be the choice between multiple, larger and more diverse environment. The inclusion of more life and diversity into such future implementations would help to avoid the feeling that one subject expressed as "slightly static". Other additions could be changes in weather, "dramatic" events occurring as the exercise progressed or the inclusion of NPCs such as animals.

A very interesting result came from the subject who was disengaged by a perceived lack of realism of the environment. He thought it to be unbelievable that people would be able to live there, in the houses placed by the road. In his opinion, the VE did not resemble a realistic setting for inhabitants, which turned the houses into objects that for him created disbelief. This is a very interesting point, and one that is definitely a worthy consideration for future instalments. It might be one of the aspects showing how this user group is unique, and possibly not as used to accepting fantastic media-made environments/designs as some other (e.g. younger) audiences.

This study differs from most of the other studies referenced in this paper, in the sense that most of these either focus on exercise/rehabilitation performance over exercise experience, or use technology to inspire exercise that was never originally intended specifically for elderly. The study also differs from all other papers referenced, by focusing on retirement home residents. This user group is a lot more challenged, both physically and mentally, than "regular" elderly users. This means that the need for specific solutions to inspire exercise is equally higher. Overall, the results must be considered encouraging for further studies. Combining retirement home residents with VR technology worked, as the majority of the residents embraced the VE technology and accepted the augmentation. The focus on the VE content design indicated solid potential as a tool to inspire regular exercise for elderly retirement home residents, with an exercise routine that is otherwise considered uninteresting. Many subjects had a truly enjoyable experience with the VE augmented manuped exercise and the majority wanted to keep exercising with this technology. Some of the statements quoted in section 6 show signs of real fundamental joy, especially compared to the attitude towards the conventional manuped exercise. And while it is an aspect that needs further and more rigorous testing to be validated, many of the user responses did show signs of intrinsic motivation with the subjects, relating to the inherent interest in the VE augmentation, and the sense of accomplishment which a sense of competency.

8 Conclusion

The results from the user study showed that it is possible for elderly users to be enthusiastic about VE technology, and that VEs can serve as impactful assistive technologies in relation to exercise, and physical therapy for retirement home residents. This study had the exercise routine of a manuped augmented, using a sunny countryside based virtual environment (VE). The majority of subjects enjoyed the addition of the VE, felt that their actions during the exercise connected well to the experience and behaviour of the VE, and had positive individual experiences with the technology – and therefore their exercise. They enjoyed being able to travel to an unknown place and the actual sense of moving while biking. They were curious to explore the environment and expressed their happiness with beautiful sights and feeling like being out in nature. 7 of 10 subjects believed that the technology improved the exercise experience and wanted to replace the conventional manuped exercise with the augmented version. 6 subjects reported that they would want to exercise more than they currently did, with this technology. Meanwhile, these results only serve as an indication, as more longitudinal studies are needed to give a more accurate impression of the benefits and potential weaknesses of this exercise encouragement method. Meanwhile, results definitely suggest that there is a lot of potential in this field, and that augmentation of the exercise routines using VEs might be a very effective method to motivate elderly users to perform regular exercise.

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