Augmented Exercise Biking with Virtual Environments for Elderly Users

Bruun-Pedersen, Jon Ram; Serafin, Stefania; Kofoed, Lise

Published in:
Proceedings - 40th International Computer Music Conference, ICMC 2014 and 11th Sound and Music Computing Conference, SMC 2014

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Augmented Exercise Biking with Virtual Environments for Elderly Users: Considerations on the use of auditory feedback

Jon Ram Bruun-Pedersem
Aalborg University Copenhagen
jpe@create.aau.dk

Stefania Serafin
Aalborg University Copenhagen
sts@create.aau.dk

Lise Busk Kofoed
Aalborg University Copenhagen
lk@create.aau.dk

ABSTRACT

Virtual reality (VR) has been shown to function well as an assistive technology to physical therapy for elderly users. Elderly users, and more specifically retirement home residents, form a unique user group in this field, due to their characteristics and demands. In a case study, retirement home residents used an audio-visual virtual environment (VE) augmentation for an exercise bike. Besides a visual display, a soundscape was played to the subjects using headphones. The soundscape was not noticed wand the headphones were found to be obtrusive. In this paper, we consider and discuss possible approaches to alternative auditory and haptic delivery methods for future studies. These nonvisual displays need to fit the requirements and limitations of the retirement home subjects who are to exercise using the VE-based augmentation from the case study.

1. INTRODUCTION

With age, many biomechanical functions decay at an increasingly faster rate. Regular physical exercise will decrease the speed of such decay, which will allow e.g. an elderly individual to retain physical independence for longer [1]. Physical therapy for the residents at retirement homes is therefore essential. But despite daily, free access to professional physical therapy and knowledge of the clear physical benefits, many residents at retirement homes rarely or never partake in regular exercise. Virtual reality (VR) technology has been shown to work well for physical therapy in relation to rehabilitation [2] [3] [4], but most studies has been made with technology that was not intended specifically for elderly. A study performed by Pedersen et al. [5] explore whether and how a VR type augmentation of a conventional exercise shows any promise as an assistive technology for retirement home residents. The aim was to a) investigate whether the elderly residents would embrace the VR technology as part of their exercise experience, and b) to mark any central parts of such experience that could be taken further and developed in future studies. The residents embraced the VE augmentation well (see later parts of this paper), but barely noticed the audio. In addition, several subjects were clearly opposed the use of headphones. As audio plays a noticeable part in our perception and experience of our surrounding environments, it should contribute to the experience of this augmented exercise. This paper therefore considers alternatives to the delivery method of auditory display as well as the possible inclusion of other non-visual stimuli. Important to consider are also the challenges related to this target group and the environment of the retirement home based exercise.

2. 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 [6]. 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 [7]. 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]. But while the Wii has proven popular for physical activation for elderly, a study by Laver et al. specifically questioned the Wii as a preferable method for rehabilitation/exercise therapy, opposed to conventional physical therapy [8]. 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, to the surprise of Laver et al., who original hypothesized that the Wii Fit would be the preferred method [8].

Literature generally suggests that VR is useful for rehabilitation purposes for elderly, and studies on overall digital interaction concerns when designing for elderly provide useful insights to the fundamental considerations necessary [6]. 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. [8].

3. PRELIMINARY CASE STUDY

At Akaciegården, a retirement home in Frederiksberg, Denmark, the exercise routine with 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). While being the preferred exercise routine, the manuped is a very static and repetitive form of exercise. 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, and that the exercise routine is predominantly not considered compelling or stimulating.

The limitations to the physical and mental capabilities of many residents narrow their ability to visit places outside the retirement home. VEs have a potential to provide some degree such of experience. In a subsequent study, 10 retirement home residents (2 females, average age: 83, SD age: 9.1) were presented with an audio-visual VE augmented manuped exercise and interviewed while using the system. Residents performed their exercise actions identically to a normal routine, but saw a VE move on a screen in front of them as they pedaled the manuped and heard a soundscape through headphones. Results showed that 7/10 subjects would prefer the VE augmented exercise to that of the ordinary form. The exercise gave the possibility to explore and travel to a place that would otherwise be out of reach for most of the users. A subject who was too obese to travel outside the retirement home without assistance stated "(…) *the sudden ability to go outside and actually 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*".

4. AUGMENTING THE VE

A sensor was placed on a manuped and connected to an Arduino board and Macbook Pro via USB. The signal was processed through Max/MSP, which checked for signal changes every millisecond.

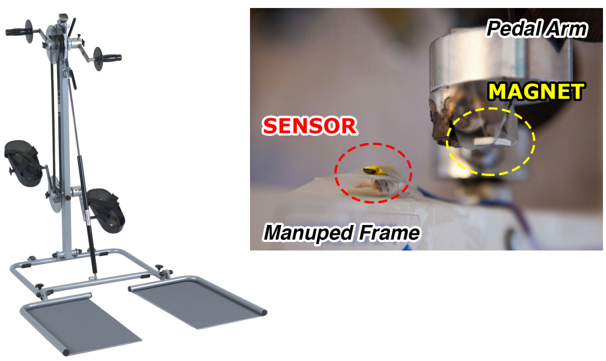

Figure 1: Left: the manuped. Upper right: the sensor on the frame and the magnet on the pedal arm.

The VE was displayed on a 1080p 46' Samsung LED monitor, running a relatively steady 40-50fps. A soundscape was played through a pair of Sennheiser HD600 headphones. The visuals of VE (see figure 2) were created in Unity3d.

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

Laver et al. address the importance of keeping the technology-interaction simple and relevant to the conventional exercise routines [8]. As such, the only interactive features of the VE augmentation were acceleration and deceleration along a predetermined path. There were no interactive auditory elements in the auditory display. The soundscape was a seamless loop displaying environmental objects by wind in the trees and grass, as well as birds singing.

5. CONSIDERATIONS ON THE USE OF SOUND AND MUSIC AS FEEDBACK

Subjects' responses were almost exclusively mentioning objects and elements from the visual display. The use of headphones as the sound delivery method was however noticed, and not popular as they were perceived as tight, warm and uncomfortable. This made it clear that a) alternative audio delivery methods would be preferable in future studies with the user group and b) that the general nature of the nonvisual display had to be reconsidered to provide a stronger impact on the subjects.

In future studies, we are interested in investigating both whether and how other forms of nonvisual feedback, such as auditory, haptic, and/or music feedback will affect the residents' experience while exercising with the VE augmentation. Below is a bullet list of often-used feedback auditory and haptic methods for displaying VEs as well as some additional auditory methods for motivating exercise. Many are interesting possibilities for future studies, while others might not fit the purpose of the user group.

Feedback from a virtual bike

- The sounds of the surfaces on which the bike is driving in the VE (e.g. when the bike is running on grass, it produces a different feedback than when running on gravel or asphalt).
- A combination of auditory and haptic feedback, so subjects both feel and hear the different surfaces.

Feedback from the VE

- Soundscapes with attention capturing elements (for example flying birds or insects), to see if subjects will divert their attention and move towards a specific place.
- Binaural sound rendering, to explore whether sound location plays a role on capturing attention.

Musical and rhythmic interaction

- Rhythmic auditory feedback, which might encourage the subjects to follow a certain tempo while biking.
- Motivational music delivered together with the experience
- Interactive versus passive music, e.g., music that changes according to the action of the subject versus the subject following the music.

Sound delivery methods

- Non-headphone delivery, that either only delivers a user experience to the active user, or combines the active user space as well as the remaining residents using the space.
- Headphones/bone conduction vs. speakers.

5.1 Feedback delivery limitations

Since there is not a lot of literature showing the content related preference for our specific user group, the unresolved issue with this list is not the novelty of the methods, but how this user group will react to these methods. The issue is that avoiding the use headphones makes isolation of the audio quite a lot more challenging. The manuped exercise in the case study was performed in a shared, social space forming the 9x12m2 physical therapy "gym", which often host 3-4 residents exercising at the same time (shown in Figure 3).

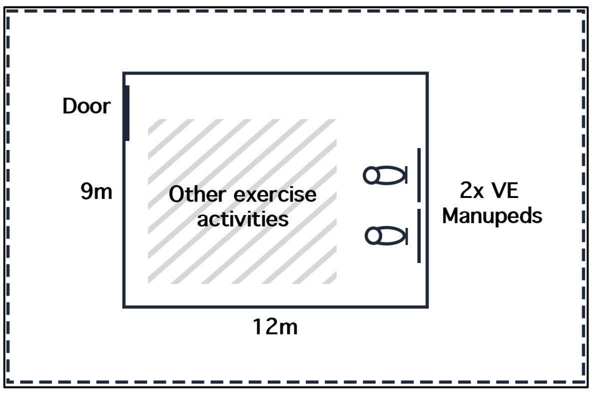

Figure 3: Top view of the retirement home "gym"

Not isolating the auditory feedback to the manuped user could negatively affect the exercising experience of other present residents. Meanwhile, a possible solution could be to not avoid feedback emission into the different "spaces" within the gym, but to use it. Each space could be given its individual subset of the feedback and with different delivery methods, which would in turn contribute something positive to its space.

5.2 Feedback possibilities for multiple spaces

If we look at the bullet list just depicted, *feedback from a virtual bike,* meaning anything related to the VE bike's interaction with the other VE elements (such as e.g. the gravel path) would be confined to the space of the manuped exercise. A current hypothesis is that sharing such information between spaces would not contribute positively to anyone not partaking in the manuped activity. Audio feedback is the more challenging part, while haptic feedback from the VE will be easily isolated to the manuped user through actuators. *Feedback from the VE* such as soundscapes and various environmental attention-capturing elements could be very interesting to share between spaces. It would be very interesting to see if such stimuli would somehow transcend the primary task with the VE user, and e.g. create additional or alternative moods for the remaining exercise space, and how it would be considered as an addition to that space for the overall exercise experience of the non-manuped users. Binaural rendering without headphones is possible through transaural audio rendering [9]. However, it would seem that cost/benefit might be low in a common space area that is noisy, with a user group with a potentially very limited hearing. *Musical and rhythmic interaction* could also reach both spaces by some of the same concepts just described, but with a different effect. Motivational/interactive music and rhythmic feedback could also transcend the spaces.

5.3 Sound delivery for the individual spaces

While haptic feedback can be applied through local actuators, and any audio delivered to the entire exercise space can be delivered through conventional speakers, isolating the sound delivery to the manuped user requires a more unconventional approach. However, this could be achieved through directional sound methods such as e.g. the SoundDome technology from Brown Innovations, which delivers 80% drop-off outside the sweet spot of the dome. Meanwhile, the SoundDome has a frequency response between 150Hz-20KHz (+/- 2dB), which limits its utilization for lower frequency feedback from the VE. Circumventing this limiting factor involves the distribution of the feedback between the different audio and haptic delivery technologies. The directional audio should be assigned to deliver only auditory cues from the feedback of the VE bike, as well as other local environmental elements that could be considered exclusively interesting to the manuped user. If this feedback extends the lower limits of the directional sound delivery, the actuators could prove a contributing factor the lower sound frequencies through vibration.

The combination could deliver a multimodal stimulus that might be perceived by the manuped user as one seamless signal, and without it interfering with the space of the additional exercising residents.

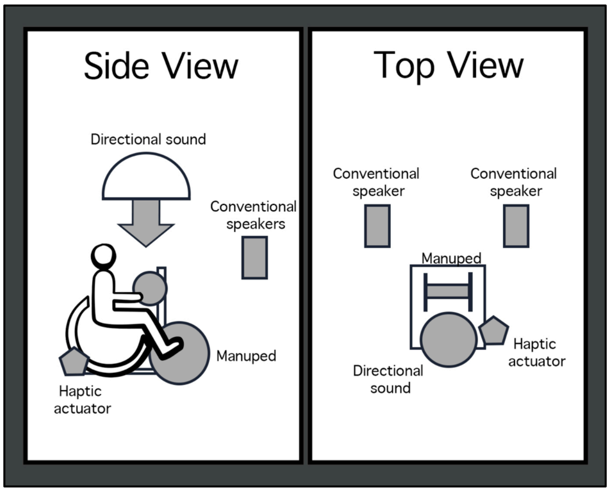

Figure 4: An audio/haptic system allowing both confined feedback for the manuped user, and conventional speakers for lower extension and spatial reach.

Using conventional speakers can furthermore support this output. They are able to deliver lower extending frequencies if needed (e.g. if the haptic feedback is deemed incapable for specific elements), and carry the general soundscape, which should serve to occlude any gaps in the directional sound/haptic integration that might otherwise be noticeable.

6. OVERALL DISCUSSION

Have we found an alternative audio delivery method and a suitable reconsideration of the nonvisual display, which provides a stronger impact with the user group? The idea for the audio/haptic delivery method is quite simple, but fits the requirements. And as academic literature on the specific field of VE exercise for retirement residents is limited. The varying mental or physical limitations are defining factors of the target group, and it places a lot of constraints on exercise equipment. Unobtrusive delivery methods are very important, and the essence of these nonvisual displays is the need for adding convincing layers and strength to the experience of driving through an environment. But there is no certainty that an audio/haptic system and the delivery methods described in this paper will work with the retirement home residents. There is, however, a definite need for more studies to map how it is possible (e.g. through VR technology) to trigger an interest for exercise with the well elderly, such as retirement home residents. The user group's reluctance of using headphones is one example of getting closer to understanding how to combine the user group and VEs.

7. CONCLUSIONS

In this paper we looked at possibilities for audiohaptic feedback for VE augmented exercise for retirement home residents. We used a preliminary case study to form a foundation for a discussion on which of a selection of relatively conventional feedback methods could be considered applicable in the context of the case study. We furthermore discussed how to implement these ideas in terms of delivery methods of the auditory and haptic displays. The results was a combination of directional sound, haptic actuation and conventional speakers to deliver a) audiohaptic feedback from specific elements of the VE augmentation in only a confined area for one user type, as well as b) shared auditory feedback for the rest of the space of the exercise facilities.

8. REFERENCES

[1] R. S. Mazzeo and H. Tanaka. Sports Medicine 31.11. Exercise prescription for the elderly. *Sports Medicine*, 31, 11 (2001), 809-818.

[2] P. D. E. de Bruin, D. Schoene, G. Pichierri, and S. T. Smith. Use of virtual reality technique for the training of motor control in the elderly. *Zeitschrift für Gerontologie und Geriatrie*, 43, 4 (2010), 229-234.

[3] M. Holden and E. Todorov. Use of virtual environments in motor learning and rehabilitation. In *Handbook of virtual environments: design, implementation, and applications.* 2002.

[4] H. Sugarman and A. Burstin. Use of the Wii Fit system for the treatment of balance problems in the elderly: A feasibility study. In *Virtual Rehabilitation International Conference* (2009), IEEE, 111-116.

[5] J. R. Bruun-Pedersen, K. S. Pedersen, S. Serafin, and L. B. Kofoed. Augmented Exercise Biking with Virtual Environments for Elderly Users- A Preliminary Study for Retirement Home Physical Therapy. In *In Proceedings of VR 2014 - Workshop on Virtual and Augmented Assistive Technology (VAAT 2014)*.

[6] W. Ijsselsteijn, H. H. Nap, Y. de Kort and K. Poels. Digital game design for elderly users. In *Conference on Future Play (Future Play '07)* (NY 2007), ACM, 17-22.

[7] E. Bainbridge, S. Bevans, B. Keeley, and K. Oriel. The Effects of the Nintendo Wii Fit on Community-Dwelling Older Adults with Perceived Balance Deficits: A Pilot Study. *Physical & Occupational Therapy in Geriatrics*, 29, 2 (2011).

[8] K. Laver, J. Ratcliffe, S. George, L. Burgess M. and Crotty. Is the Nintendo Wii Fit really acceptable to older people?: a discrete choice experiment. *BMC Geriatrics 2011 11:64.* , 11, 64 (2011).

[9] T. Funkhouser, N. Tsingos and J. Jot. "Survey of methods for modeling sound propagation in interactive virtual environment systems. (2003).