ABSTRACT

Virtual reality (VR) exergames provide a unique opportunity for developing safe and effective therapies for older adults at assisted living facilities. This group of people has an increased risk of falls, which can lead to severe injuries and increase the risk of falls even further. An early detailed individualized assessment and treatment intervention for older adults with preexisting conditions is recommend, but the workload for physicians is high and training is often perceived as boring because exercises generally do not change that often.

In this paper we introduce a seated VR exergame for fall prevention of older adults. The game has been designed and developed together with clinical experts and therapists to provide adequate fall prevention exercises, which can be implemented in patients daily schedules and administered through a VR exergame. Movements that control the exergame match the motions suggested by our partner physicians and improve balance by shifting the players center of mass.

Index Terms: Human-centered computing—Human-computer interaction (HCI)—Interaction Paradigms—virtual reality;

1 BACKGROUND & MOTIVATION

One in three people over the age of 65 fall annually, with the majority of these being caused by balance disorders [4]. Balance disorders in older people have wide-ranging physical and psychological consequences and increase the likelihood of frailty, cognitive decline, sedentary behaviour, social exclusion, falls and injury related death [8]. The National Institute of Clinical Excellence (NICE) UK Guidelines (2013) recommend an early detailed individualized assessment and treatment intervention for older adults with balance disorders at risk of falls [7].

However, physiotherapy is generally only administered, if a patient had a previous fall, is at immediate risk or recuperating from some other illness. This means, that older adults without these issues are not treated professionally, even though they belong to an at-risk group. At the assisted living facility, there are only a few programs available, which encourage patients to exercise. (e.g. “Nordic Walking”, strolls and swimming)

Balance and coordination degrade with age in general, but training is very effective to improve both. For instance, as recounted by the physicians we interviewed, it is possible to stabilize a patient through seated exercises enough for them to spend more time standing as opposed to sitting or supporting themselves.

Our goal was to create an exergame, which enables all patients — even those without previous ailments — to improve their balance and coordination for their daily life. Serious exergames are applied in a multitude of different situations and have shown to be effective in improving health and habit of users [5, 9]. A seated VR exergame is the perfect point of entry to regular exercise due to low physical requirements. Gamification in general has proven to be a motivating aspect [2], as seen in other computer-generated experiences and analogus competitive games they play. In physiotherapy, patients are motivated when improving and getting closer to their goal, so an important design choice is a goal-oriented gameplay with short feedback loops.

Programs such as the OTAGO [1] or FaMe [3] feature catalogues of exercises for fall prevention with detailed instructions and accompanying illustrations. Selection from such catalogues should still only be done by physicians, since depending on context and condition of the patient, only some be beneficial. Furthermore, most of these exercises are not focused on seated movements, but instead use standing or repeatedly sitting down actions, which further increases the risk of falls during training. Older adults and accompanying therapists can feel insecure when introduced to immersive head-mounted-displays (HMDs) and would rather sit down to feel safe when experiencing VR. Hence, we focused on seated exercises and created the VR exergame for seated VR experience as described in Section 2.

This work is part of a larger funded project [10], which also focuses on treating neurological diseases. As part of this work, we particularly focused on analysing and developing exergames for a seated VR experience and discuss the results in the following.

2 SEATED VR-BASED BALANCE TRAINING

To find suitable exercises for our VR exergame, we conducted multiple interview sessions with physicians at a nearby assisted living facility for older adults. At earlier interviews, we discussed the area of fall prevention exercises especially in comparison to currently applied exercise programs such as the OTAGO. It turns out, that even though some exercises considered by the physicians match or closely resemble those from the established programs, the focus was always two-folded: Exercises at this facility focus on (i) improving balance and (ii) functionality in the patients’ day-to-day life. Furthermore, the results of the interviews with physicians revealed the following issues, which had to be addressed in the VR exergame:

- Exercises should feature a wide range of motions. Muscles should be stretched to their limit so that more areas of the muscle are activated and mobility is improved thoroughly.

- Exercises should focus on single aspect and not be combined with others. For example, when stretching the leg the patient should not rotate their arm at the same time. These combined

Figure 1: Dynamic exercise where the patient has to extend their arms and move objects. This is comparable with the task to grab and place objects such as cups or kitchen utensils.
exercises are too complicated and the patients are more likely to make errors.

- Each set of exercise should start at a low difficulty, because patients are often unrealistic and too confident in estimating their abilities, and might eventually injure themselves.
- The exercise should be either self-explanatory or should make use of detailed visual instructions.

![Figure 2: Exercises that shift the center of mass whilst sitting. Top two images show exercise 1) which has a good training effect, but is not used often in daily activities. Movements in exercise 2) are important when having conversations and facing the other people. 3) The player can see and feel the camera in VR. By placing targets around the player, they move their arms and torso to take pictures while doing the exercise automatically.](image)

Based on these initial assessments, we developed first prototypes of exergames, which we demonstrated to the physicians together with patients in focus groups at the facility. After further collecting feedback, we were able to create a catalogue of exercises for fall prevention. The exercises are separated between those that need legwork, and those that do not (which are ideal for sitting patients). They were valued by physicians for training effectiveness and day-to-day usefulness. We present three types of exercises in the following:

### Sitting, rotating the head and extending the arms

This exercise has a medium training effectiveness, and a high day-to-day applicability, since it resembles reaching for objects and moving them. Figure 1 shows an example of the exercise in our catalogue. This is an ideal exercise, since it improves coordination, muscle tissue and balance by shifting the patient’s center of mass. If the patient follows through with the head rotation, they will automatically rotate their upper torso as well, which addresses even more areas.

### Sitting, tilting the head left, right, front, back

The exercise illustrated in Figure 2 (top row) is a very simple, but effective method to provoke a continuous shift in the patient’s center of mass. In daily life this activity though is not very common, yet using a modern digital camera, and press the trigger. Several tasks variably require the user to “zoom in” by extending their arms all the way, and “zoom out” by bringing the camera closer to their face as seen in Figure 2.3. Other tasks also ask the user for a portrait photo instead, having them rotate the camera whilst extending the arms. These assignments resemble the exercises suggested by the physicians as described above.

### Sitting, rotating the torso and head at the same time

As shown in Figure 2 (bottom row), training effectiveness is reduced, since the movement of the head in conjunction with the torso does not shift the center of mass as much as in the previous exercises. Physicians rated the everyday applicability very high though, because this motion is involved in a variety of other movements such as turning in conversations and preparing for (grasping-) interactions.

To stimulate the performance of these exercises in a gamified VR experience, we created an application in which the player is a newspaper reporter, whose task it is to take pictures for the next headline. The patient is given a 3D printed camera, physically modelled to feel like an older model, which is also virtually visible in the VR exergame (see Figure 2.3). Targets, which have to be photographed, are located all around the player, so that the player needs to turn towards the next target in order see it. For taking the picture, the patients have to move the camera in front of their face, as if using a modern digital camera, and press the trigger. Several tasks variably require the user to “zoom in” by extending their arms all the way, and “zoom out” by bringing the camera closer to their face as seen in Figure 2.3. Other tasks also ask the user for a portrait photo instead, having them rotate the camera whilst extending the arms. These assignments resemble the exercises suggested by the physicians as described above.

### 3 Conclusion

Seated VR exercises for fall prevention are very promising for older adults at assisted living facilities. They should be accessible by anyone who is interested and not gated by missing health issues, since prevention is an important step in increasing their confidence and overall well-being.

We are planning to run a larger study in the next few months and expect to find more exercises that are suitable and numbers to evaluate long-term training with our exergame. All exercises will also be evaluated quantitatively using a motion capture system in a state-of-the-art living lab [6].

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