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SmartAktiv: A Tablet- and Virtual Reality-Based Training for Individuals With Cognitive Decline

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ABSTRACT

Dementia is an age-related condition associated with increased disability and mortality, and long-term care utilization. New technologies are needed to detect and monitor cognitive decline in at risk populations for developing dementia. Computerized training programs have been developed for people with dementia and mild cognitive impairment on the basis of various technologies. Yet, to the authors' knowledge there is no combination of tablet and immersive VR training that (1) has been developed with and for people with cognitive decline, and (2) targets intelligent multimodal activation and training of activities of daily living within meaningful/leisure activities. The SmartAktiv project aims to design a tablet- and VR-based training with and for individuals with cognitive decline and examine the effects this training exerts on older adults' quality of life and on the performance of selected activities of daily living (e.g., finances, medication). In addition to that, the SmartAktiv project concerns the AI-based development of digital biomarkers for dementia as well as various screening tools and questionnaires.

Keywords: Virtual reality, Eye tracking, Digital biomarkers, (I)ADL training, Quality of life, Usability

INTRODUCTION

Projections show that as the population ages and grows, dementia rates will increase worldwide (Nichols et al., 2022), with dementia cases predicted to triple to 131 million by 2050 (Prince et al., 2016). Dementia is a neurogenerative disorder that is characterized by memory impairment and cognitive decline. As a result, people living with dementia experience an increase in care dependency as the disease progresses, which affects their functional status (Alzheimer's Association, 2023; Schüssler et al., 2016), i.e., one's ability to execute activities of daily life (ADL; Lawton & Brody, 1969). While in the earlier stages of dementia difficulties arise in performing instrumental activities of daily living (IADL), such as managing finances or using the telephone, as the disease progresses, difficulties arise in performing basic ADL, such as dressing (Giebel et al., 2015). In light of these concerning projections and the impact dementia has on individuals and societies, there is a growing need to develop interventions for both the prevention and treatment of dementia.

CONTEXT AND RELATED WORK

Cognitive decline is prevalent among older adults, with dementia representing the most severe form and also the main cause of disability currently affecting about 50 million individuals across the globe (World Health Organization, 2019). Studies have shown that subjective cognitive decline (SCD) and mild cognitive impairment (MCI) increases the risk for developing dementia (Mitchell et al., 2014). While individuals with SCD only perceive a subjective cognitive change (Röhr et al., 2020), those with MCI already exhibit an objective mild cognitive impairment (Petersen, 2016). Before the onset of dementia, individuals may experience difficulties in IADLs. In the review of Jekel et al. (2015), the authors examined 37 studies, 35 of which reported IADL deficits in patients with MCI (Petersen, 2004). Financial capacity emerged as the most commonly affected IADL in MCI patients (Jekel et al., 2015). MCI patients advance to dementia more quickly than non-MCI patients (Petersen, 2004), but cognitive deterioration in MCI patients can be slowed down (Jean et al., 2010; Ngandu et al., 2015). Consequently, early detection and monitoring of functional status in MCI as well as in dementia is of particular importance (Livingston et al., 2017), as are timely interventions (Alzheimer's Association, 2019). Therefore, the development of tools to identify populations at high risk of developing dementia, such as MCI, is of great importance.

Non-pharmacological interventions, such as multicomponent interventions, have shown promise in improving cognitive function. For example, (Ngandu et al., 2015) found that a non-pharmacological multicomponent intervention significantly improved neuropsychological test scores, executive functioning and processing speed in MCI patients. Similarly, technology-based interventions, including computers and virtual reality (VR), have also been used for cognitive and physical exercises. Such training programs have shown promising results in improving quality of life (QoL) and different domains of cognition (Hagovská et al., 2017; Man et al., 2012; Zuschnegg et al., 2023) among individuals with MCI. For instance, Chen et al. (2020) reported that a tablet-based training program targeting cognitive abilities improved IADL scores compared to a control group among non-MCI patients. On the other hand, VR interventions, such as those developed by Shin et al. (2023), have shown potential in improving ADL-training through simulated scenarios like 1) cooking food, 2) dressing, 3) ordering food, 4) grocery shopping, and 5) cleaning.

Although both tablet- and VR-based interventions have been used in (I)ADL training, previous interventions failed to achieve convincing effects. Furthermore, to the authors' knowledge, there is currently no combination of tablet and immersive VR training that (1) has been developed with and for people with cognitive decline, and (2) targets intelligent multimodal activation and (I)ADL training within meaningful/leisure activities.

The aim of the SmartAktiv project is to design a tablet- and VR-based training for individuals with cognitive decline (Figure 1) and to examine the effects this training exerts on older adults' quality of life and on the performance of selected (I)ADLs (e.g., finances, medication). In addition to that, the SmartAktiv project concerns the correlation of digital biomarkers for dementia and different screening tools and questionnaires. Exploratory studies with eye movement measurements in VR were quite promising. Paletta et al. (2021) extracted eye movement features, such as blink rate, while participants observed a three-minute video. Through eye movement analysis they could reliably distinguish between people with early Alzheimer's disease and healthy controls.

(a) (b)

Figure 1: (a) Application of the tablet-based multimodal activation app of Joanneum Research in the nursing home (credit: Joanneum Research / M. Schwarzl). (b) Application of VR-based user journey (credit: VitaBlick GmbH).

TABLET- AND VR-BASED TRAINING

Tablet Training System

The tablet-training that will be used in SmartAktiv was developed as part of earlier projects (AktivDaheim: EK: 1505/2016, AMIGO: EK:30-401ex17/18, and multimodal: EK:31-556 ex18/19) offering a choice of 44 topics with 16 available exercise types (e.g., quizzes, puzzles, gap texts, mathematics). The "multimodAAL app" (Mapp) has already proven to be very suitable for cognitive activation among older people: In a 6-month RCT study, training with the Mapp resulted in a preservation of cognitive status compared to the control group (Berger et al., 2022) and AI-based digital biomarkers were identified for the screening of cognitive deficits (Pszeida et al., 2023). The following exercise types were selected for the training: quiz, outsider, mathematics, puzzle, gap text, and step sequence.

VR Training System

Pico 4 Enterprise devices will be used for the application of VR. The standalone devices include an eye-tracking and a hand-tracking function via four integrated RGB cameras that allow users to see their own hands in the VR application and perform certain simple tasks (e.g., by clicking on certain objects, i.e., a chestnut). The VR headset has a resolution of 4320 × 2160 pixels and a refresh rate of 90 Hz. It weighs 586 grams, distributed evenly across the front and back of the VR headset in a senior-friendly manner, ensuring a stable weight distribution and comfortable wearing experience.

Eye Tracking

A five-point calibration method will be used, where the user concentrates sequentially on five relevant points, displayed like target symbols (Paletta et al., 2021). In the VR-training environment we then obtain data about the intersection of the eye gaze vector with the VR objects and with panoramic images or videos in 2D space. Image coordinates are calculated relative to the orientation of the eye orientation axis, which serve as the basic unit of measurement for quantifying attention.

For a general characterization of gaze behavior, the following features will be measured, (i) Concentration in the sense of deliberate focusing of attention on a specific activity (Paletta, Brijacak, et al., 2019), (ii) cognitive load on the basis of correlating characteristics from eye-tracking data (Paletta et al., 2015) as well as in the specific context of multitasking load (Paletta et al., 2020), as it is specifically used in specific serious games (Paletta, Grabher, et al., 2019), and finally (iii) indicators for the measurement of inhibition in a VR-based version of the anti-saccade test (Paletta, Pszeida, et al., 2019) and for stress in the form of the Task Switching Rate (Paletta, Brijacak, et al., 2019).

Bio-Signal Data

Bio-signal data such as heart rate and heart rate variability are recorded using a smartwatch (Garmin vivosmart 5) to measure the participant's mental state (i.e., cognitive-emotional stress) during training (Schneeberger et al., 2022). These data would be valuable for analyzing the relation between stress and cognitive performance during the intervention.

METHODS

Study Design and Recruitment of Participants

In a first phase, data from previous VR-studies (e.g., Haeussl et al., 2021) were examined and discussed in an expert workshop ($n = 6$), a focus group ($n = 7$ people with cognitive decline), and an interview ($n = 1$ person with cognitive decline). Participants were recruited by the Geriatric Health Care

Centers Graz, Albert Schweizer Institute for Geriatrics and Gerontology. The focus group and interview were held at a nursing home in Graz, Austria.

In a second phase, a usability study with $n = 9$ participants with cognitive decline and $n = 3$ health professionals will be conducted to adjust the tablet-VR-system. In the third and final phase, the tablet-VR-system will be tested in a one-month pilot study ($n = 30$) including participants with subjective cognitive decline, mild cognitive impairment, and moderate cognitive impairment based on the MoCA classification (Fisher & Thomson, 2014; Nasreddine, n.d.). Participants will be asked to complete each scenario (combination of tablet- and VR-based training) at least once. Each session will last for approximately 46 minutes and include tablet and VR-based training as well as pre- and post-training measures, such as the Simulator Sickness Questionnaire (Kennedy et al., 1993). Collected data will comprise quantitative data from questionnaires/scales, sensor data from the VR-glasses and biosensors, and qualitative data from interviews assessing, for instance, usability and experience.

Data Analysis

Qualitative content analysis (Schreier, 2012) was performed on the transcribed audio-recorded focus group and interview of phase 1. Based on the interview guide, we developed a concept-driven coding frame with main and subcategories. This coding frame was then supplemented with data-driven subcategories based on the audio transcripts. As a last step, main and subcategories were summarized, interpreted and discussed with the research team. MAXQDA (Version 2018) was used for qualitative data analysis. The same procedure will be adopted in the second and third phase of the study. Quantitative analysis (i.e., pearson/ spearman correlation coefficients) will be conducted using SPSS.

RESULTS

Sample Characteristics (Phase 1)

The average age of participants was 77.39 ($SD = 6.38$) and 71.43 % were female. The majority (57.14 %) reported a high level of education (A-levels or a university degree), 28.57 % reported a medium and 14.29 % a low level of education. A total of three people received care allowance.

Focus Group and Interview (Phase 1)

The expert workshop collectively agreed upon four scenarios (see Figure 1) for further development. The tablet- and VR-based training should envelop an entire journey, i.e., starting with planning the trip, buying tickets, traveling to the respective destination, activities on site, and ending with the return journey. A total of three scenarios (beach, winter, city; Figure 2) were then discussed within a focus group. The hike-scenario was subject of an additional interview. The focus group, respectively the interview, provided insights into the design of the avatar, the means of transport, and planned activities onsite. Although the environment tended to be seen as more relevant than the avatar, participants expressed some criticism. The presented avatar in the VR was generally perceived as too artificial and not perceived as one's own body. The texture and stiffness of the hand were particularly noticeable. As regards the means of transport, participants prioritized the train, bus and car, over plane, due to ecological concerns. Scenario unspecific activities were food shopping or visiting a restaurant. Scenario specific activities encompassed going for a walk on the beach (beach), skiing (winter), visiting a museum or concert (city) and collecting forest objects such as mushrooms (hike).

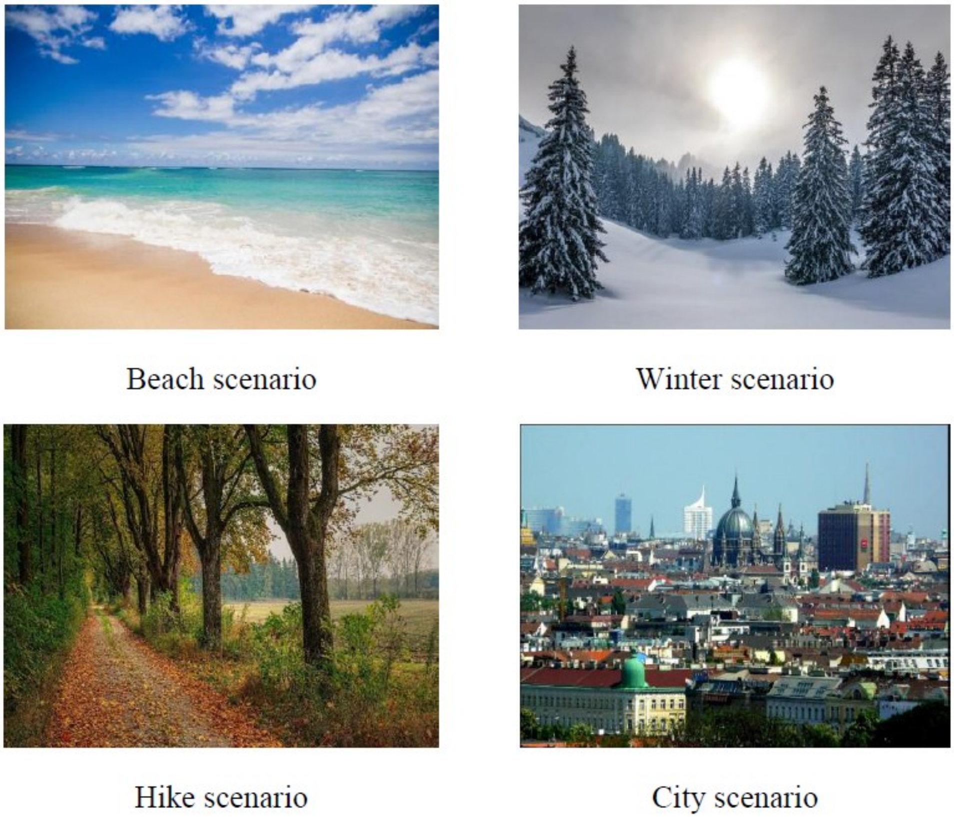

Figure 2: Contents of the VR scenarios.

CONCLUSION

In this paper, we have introduced the SmartAktiv project and reported preliminary findings of the first project phase, i.e., the design of the training program. SmartAktiv sets out to combine tablet- and VR-based exercises that target multimodal activation and (I)ADL training (e.g., finances) within meaningful/leisure activities designed with and for older adults with cognitive decline. We will evaluate the proposed intervention in a final pilot study with regards to older adults' quality of life and the performance of selected (I)ADLs (e.g., finances, medication) as well as the training program's usability. Within the SmartAktiv project and through eye-tracking analysis, we want to advance research on digital biomarkers. In this context, we will correlate digital biomarkers for dementia with scores from various screening tools and questionnaires.

In terms of content, the combined tablet and VR training will envelop an entire journey, from planning the trip to the departure. The expert workshop selected four scenarios which were then discussed within a focus group and an interview. Qualitative data provided insights into the avatar design, the means of transport and activities to be performed within the VR.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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