Recommendations on the Design of Serious Games for People with Dementia

Corinna Simone Dietlein[1],* and B.N. Otmar Leo Bock[1]

[1]Institute of Physiology and Anatomy, German Sport University Cologne, Am Sportpark Muengersdorf 6, 50933 Cologne

Abstract

Dementia is a progressive syndrome affecting cognition, motor abilities and behavior. Serious games are an emerging treatment alternative but benefits have not been found for people with dementia yet. One reason may be that serious games were not well adapted. The purpose of this article is to give informed recommendations on the design and implementation of serious games for people with dementia that future studies can apply and thus may find significant effects. The methodology applied was deriving information from existing literature in combination with experience from personal work in the field. Main findings are: implementation of well-contrasting icons; first-person game perspective; gesture control; personalized game content; combination of only one cognitive and one motor skill; implementation as supervised group activity. In conclusion, the recommendations are a novelty and represent a profound guidance in the design and implementation of serious games for people with dementia

---

*Corinna Dietlein. Email:corinna.dietlein@stud.dshs-koeln.de

1. Introduction

Dementia is a chronic and progressive syndrome which affects cognition "beyond what might be expected from normal ageing" (1). Alzheimer's disease (AD) contributes to 60-70% of all cases (1). Executive functions are affected including comprehension, attention, information processing, decision-making and planning, together with memory, learning, orientation and language skills (2). Cognitive impairment is accompanied by the loss of motor functions, such as balance, gait, flexibility or strength (3). Further, behavioral disturbances commonly occur with dementia, e.g. verbal and physical aggression or sleep-wake disturbances (4). According to "The Global Deterioration Scale for Assessment of Primary Degenerative Dementia" by Reisberg et al. (1982), the course of dementia can be divided into two phases comprising seven stages: the pre-dementia phase (stages one through three) and the dementia phase

(stages four through seven) (5). In the early pre-dementia phase, no cognitive decline is evident (5). This is followed by a very mild decline, which can be considered as "age associated memory impairment" merging into a "mild cognitive decline" where first deficits e.g. in finding words and names or becoming lost in unfamiliar places become evident (5). The first stage in the dementia phase is considered as "mild dementia" with a moderate cognitive decline and is characterized by e.g. forgetfulness, losing track of time, memory deficits and problems of handling finances (1,5). The second stage in the dementia phase is considered as "moderate dementia" with a moderately severe cognitive decline and is characterized by e.g. forgetting well-known phone numbers or addresses, requiring help with (instrumental) activities of daily living ((I)ADL) such as choosing proper clothing, or even facing balance problems (1,5). In the last two stages of the dementia phase (moderately severe dementia and severe dementia), cognitive decline is severe or even very severe

(5). People with dementia (PwD) are dependent on extensive assistance in their daily life, e.g. when it comes to personal care such as toileting and eating (5). They experience behavioral disturbances (e.g. delusional behavior, agitation, aggression or anxiety symptoms), become completely unaware of time and place, have major difficulties recognizing relatives and friends or show inability to walk (1,5). There are around 50 million PwD currently (1). The number of PwD is rising constantly and ten million new people are diagnosed with dementia every year (1). Over 150 million people will live with dementia by 2050 (1). Following ischaemic heart disease, stroke, chronic pulmonary disease and lover respiratory infections, dementia is in the fifth place accounting for global deaths (6). In 2015, 818 billion US dollars were spent on dementia globally and costs are expected to increase to more than 1 trillion US Dollars in 2030 which makes dementia constitute an equally high economic burden as cardiovascular diseases (7,8).

Currently, there is no treatment available to cure dementia [1]. Traditional treatment of dementia consists of drug therapy in combination with cognitive and/or physical training. A meta-analysis investigated the efficacy of drug treatment on cognition and found that drugs had only a small, however significant, impact (9). The same meta-analysis also investigated the impact of physical exercise on cognition and found that it potentially improved cognitive functioning (9). A review analyzed the effect of cognitive training as a form of non-pharmacological intervention in people with mild to moderate dementia (10). The review found that there was "still no indication of any significant benefits from cognitive training" (10) and that "available evidence regarding cognitive training remains limited" (10). However a meta-analysis found that "cognitive training evidenced promise in the treatment of AD, with primarily medium effect sizes for learning, memory, executive functions, ADL, general cognitive problems, depression, and self-rated general functioning" (11). The discrepancy between the findings of the two articles resulted from the methodological differences they applied. The latter one "applied much less strict inclusion criteria and included both randomized and non-randomized trials as well as studies that included patients with moderate to severe AD" (10). One review found that physical activity was beneficial in all stages of dementia where "best results were obtained in the interventions with the largest training volume" (12). "Multicomponent interventions (e.g. a combination of endurance, strength and balance) led to larger improvements in gait speed, functional mobility and balance, compared to progressive resistance training alone" (12). A meta-analysis "found a significant effect of exercise programs on the ability of people with dementia to perform ADL" (13). However, this meta-analysis suggested caution in interpreting findings since unexplained statistical heterogeneity was observed (13). Thus, effects of traditional treatment vary between different studies and do not seem enough satisfactory for PwD.

In the age of digitalization, an emerging treatment alternative in the field of dementia is training by means of serious games (SG). This treatment approach makes use of "technology to combine three components which are multimedia, entertainment, and experience" (14), and are defined as "any meaningful use of computerized game/game industry resources whose chief mission is not entertainment" (15). The term "serious" indicates that the games aim for training, education and health improvement. SG include physical and/or cognitive components and comprise computer games, training simulation, as well as sports or board games (14).

Serious games provide a low-cost treatment method that can easily be installed in the user's home (16) or a daycare facility. It provides the option of experiencing and training real-life activities in a virtual environment for people who may no longer be able to engage in such real-life activities due to cognitive and/or physical impairment. A systematic review addressed the scope of SG used with PwD as well as their feasibility and effectiveness (17). Regarding the scope, a great variety of SG interventions was reported. One study administered for example a music intervention where PwD could play a virtual keyboard (18). In another study, PwD had to scratch virtual bubbles floating over a screen (19). Another study applied cooking games, interaction with music apps and Google Maps and balance training through the Nintendo Wii® (20). Nintendo Wii® was also applied in two other studies where PwD played bowling, yoga, strength and balance games (21,22). In yet another study, PwD had to find a certain room or certain targets in a virtual apartment (23). One study applied a game with IADL tasks such as grocery shopping or taking the bus (24).

Regarding the feasibility of SG for PwD, the review concluded that this user group needs support from caregivers to understand the game content and to handle technical equipment (e.g. remote control). Feasibility analysis also revealed that PwD enjoyed playing SG, especially when they were conducted in groups. With this social interaction and communication between players were fostered (17).

Effectiveness analysis in the review article comprised results on cognitive function, physical function and personal/behavioral aspects. However, outcomes were diverse. The one study that applied Nintendo Wii® yoga, strength and balance games did not identify significant effects on cognition. Two studies found significant improvements in cognition in their computer-assisted cognitive training groups. Improved areas were for example attention, calculation, language, memory, orientation and learning. However, they found significant improvements also in their comparative intervention group that received non-technical cognitive programs. Two studies found positive effects on cognition only in their computer-assisted intervention group. One study could identify stable Mini Mental State Examination (MMSE) scores in their intervention group receiving computer-assisted cognitive

training and a significant cognitive decline in their comparative intervention group receiving an aspecific cognitive training program. Regarding physical outcomes, the one study with the Nintendo Wii® yoga, strength and balance intervention found improvements in balance and gait. However, they could also identify balance and gait improvements in their comparative intervention group that received a simple walking intervention. One study found greater improvements in daily functions in the intervention group receiving a non-technical cognitive program. Three studies could not identify significant effects on physical function in any of their study groups. Regarding personal/behavioral aspect outcomes (e.g. quality of life), three study could not identify changes in any of their intervention groups. One study found significant improvements in their computer-assisted intervention group, whereas another study found greater positive changes in their intervention group without the computer-assisted program (17).

Taken together, the review concluded that available studies allow no firm conclusion on the presence of added benefits when SG are played in addition to traditional interventions (17). One possible reason for this lack of consistent data is the large heterogeneity of available studies regarding, e.g., intervention length, intervention content and outcome measures. A second possible reason is the low methodological quality of some studies (e.g., external validity, representativeness of study participants and randomization of study participants). A third possible reason is that some of the SG administered in the past were not well adapted to the needs of PwD. The recent article addresses the latter issue.

The purpose of this article is to give informed recommendations on the design of SG for people with mild to moderate dementia, based on existing literature and personal work experience in the field. These recommendations are intended to provide a guidance in designing SG that specifically meet the abilities and needs of PwD. Thereby, the prime concern is the ease of access of SG for PwD, which is the prerequisite for motivation and enjoyment of engaging in SG. With this, the recommendations further aim to support social interaction and to reduce behavioral disturbances. Additionally, a regular engagement in SG may also help to improve cognitive abilities (17) and to achieve physical activity recommendations by the World Health Organization (WHO) (150 minutes of moderate-intensity activity in bouts of at least ten minutes duration throughout the week for adults of 65 years and above) (25). Therefore, studies included in the available systematic review (17) were screened. Additionally, a non-systematic literature search on studies comprising SG for PwD was conducted and relevant articles (only inclusion criteria were SG and PwD) were screened. The included studies aimed, for example, at improving behavioral symptoms, cognitive performance, balance and gait (18,19,21), but also exploring acceptability, pleasure and social engagement (19,20). Personal work experience

was contributed by one of the authors (CD) who worked as researcher in a SG project called "MobiAssist" (26), which was specifically designed for, and administered to, PwD. While MobiAssist was still in the developing phase, CD used it for personal research interests (development of an observer-rated usability scale to evaluate the effectiveness, efficiency and satisfaction of SG for PwD) and played it with a group of PwD in a daycare facility twice a week for 45 to 60 minutes over four weeks. Second, in the actual research project, CD installed MobiAssist it the PwD's homes, explained the technical components and how to play the games so that they could use the SG independently over four months. Furthermore, CD was involved in troubleshooting during the intervention period, and conducted structured interviews with the PwD and their caregivers after the intervention, to retain information on how they experienced MobiAssist, how they integrated gaming into their daily routines, what difficulties they encountered or what games they liked and disliked the most. This specific methodology that combines knowledge from the literature and first-hand work experience was chosen for the synthesis of holistic information that encompasses the broad field of dementia work. With this, we would like to ensure that all aspects, from the theoretical background to the practical working field, are consistent and complementary when giving recommendations appropriate for the specific target group of PwD.

2. Technology used, Observations, Recommendations

2.1. Input and output device

Eight studies used a touch screen or a PC keyboard in combination with a PC mouse (20,24,27–32). Touch control, keyboard and mouse require fine motor skills on a relative small (Tablet) PC screen. Seven studies used gesture control which comprises movements of upper and lower limbs and requires certain motor functions such as balance (postural control, weight shifting, and lateral stepping), eye-hand coordination or reaching beyond one's arm length (19–21,33–36). Movements are monitored on a big (e.g. TV) screen in front of the player. Five studies used a remote control (four used Wiimote; one used a joystick) (18,22,23,37,38). The Wiimote is used as a remote control and features different buttons. The player holds the Wiimote in their hand and moves their arm or wrist to move a cursor on a TV screen for pointing purposes. Buttons on the Wiimote are pressed and released for enter purposes. One study modified the Wiimote by providing a "Wii Pistol" (a case for the Wiimote) for better a handgrip and reduced wrist movement amplitude and additionally programmed all buttons having the same enter function (18). Another study modified the Wiimote by covering all but one button on the Wiimote (38). The joystick functioned as a remote control to move through a virtual apartment (23). It featured a button

that could be pressed to log in game targets. In MobiAssist, a remote control was not used for pointing purposes but only for entering purposes. It featured five different colored buttons. One study featured a stationary bike with a blue and a yellow button on the steer connected to a screen (39).

The advantage of gesture control over a remote control is that PwD do not need to familiarize with new devices and learn and remember different functions of buttons. Studies that used remote controls often reported that PwD had difficulties in operating the devices and needed extensive help by caregivers (18,37). From my personal work experience with the MobiAssist remote control, I observed that PwD often did not understand when to press which button to log in the correct answer out of four answer options shown on the screen. They had difficulties to associate the colors on the remote with the colors that framed the answers on the screen. However, I believe that if the design of the remote control is kept simple (e.g. without wires or different colors and with only one button) and if the remote control is used for pointing together with entering purposes, an intuitive use could be achieved, too.

Since PwD often face visual problems and have reduced fine motor skills (18), pointing and moving their fingers on a small Touch PC or typing on a keyboard and moving a PC mouse could be quite challenging. Additionally, people, who have now reached an age of 65 and older, were not born and raised in a time where computers were part of one's daily work and private life. PwD might have never interacted with a virtual environment or might not be used to technical equipment. Familiarization with such new games might already be overwhelming for older people without dementia and thus might be even more challenging for PwD.

A stationary bike provides the advantage that practically everyone knows how to cycle and thus no further explanation on how to pedal is necessary. Additionally, PwD who have balance problems or get easily fatigued when standing for too long, could easily exercise on a stationary bike as they are seated, can hold on to the steer and only have to move their legs. Disadvantage of a stationary bike in a virtual environment is the limited physical training diversity - stationary bikes would only exercise the lower limbs.

Recommendations

- The input should support the natural movements to execute game tasks (e.g. stretching arm above when reaching for an object on the upper frame of the 2.2. Feedback.
- To keep cognitive requirements to a minimum and to foster intuitive use, gesture control is preferred over remote control input devices and PC keyboard and mouse.
- If PwD show restricted motor abilities (e.g. because of pain or limited joint mobility), a remote control (such

as the cased Wiimote with only one active button) could be used instead.
- Stationary bikes could be applied when training of lower limbs is desired explicitly.

2.2. Feedback

In one study, PwD played a song on a virtual keyboard by clicking on keys that were highlighted successively (18). If they clicked on the wrong key, the system gave immediate feedback by reducing the volume of the note played. Nintendo Wii Bowling®, which was applied in three studies (22,37,38), provides immediate feedback through showing the player a screen with the fallen pins and with the pins that are still standing. One study explicitly mentioned that their virtual memory program provided immediate audiovisual and positive feedback (24). In MobiAssist, PwD played a quiz game where they had to choose the right out of four given answers. Immediate feedback was provided: if they picked the wrong answer, the background was highlighted in red; if they picked the right answer, the background was highlighted in green. Four studies and MobiAssist provided feedback on game scores, errors and time needed for task completion (31,34,37,39).

To reinforce learning (memory) strategies, providing immediate and positive feedback (e.g. audio or visual signals as mentioned above) is important (24) and could prevent PwD from frustration and the loss of motivation. Adapting feedback to the player's visual and hearing abilities could be done by giving audio feedback for PwD with visual impairment and vice versa. From my personal work experience in the field of SG in PwD, I got the impression that a summary screen at the end of a game is valuable when SG are played in groups. With that, players can compare their performance among the group. This fosters competition and enhances social interaction. Comments, such as "Wow, you got nine out of ten questions right." or "Amazing, you completed the task in under a minute." were fixed parts of the sessions.

Recommendations

- SG should provide immediate feedback adapted to the player's visual and hearing abilities to foster motivation and prevent frustration.
- A summary screen showing scores, errors or time is recommended to foster competition and social interaction.

2.3. Instruction and assistance

Sixteen studies reported that instructions and introductory sessions (explanation of technical equipment and content of SG, and exemplary demonstration of games) were given by the caregiver or research personnel, respectively (20,22,24,29–35,37–39). Ten studies reported that they provided repeated assistance on technical equipment and

game content or physical help to perform required movements (18,20,22,23,27,32,33,37–39). One study reported that daily instructions were necessary to help the participants remember the game content (33). MobiAssist is an example for in-game instructions provided for the players. Slides with written instructions and pictures or short video sequences are shown before each game. Instructions were formulated over several slides that PwD could click through or skip.

From my personal work experience with MobiAssist, I could observe that instructions were too long and formulated too complicated for PwD to remember. As soon as the game started, PwD had already forgotten the instructions and asked "So, what am I supposed to do now?". Thereupon, the caregiver had to summarize the instructions and explain the game while the PwD was already playing. Thus, it seems that written explanations fail the mission of explaining game tasks. The majority of literature analyzed also shows that playing without assistance is almost impossible for PwD. There is an obvious need for a caregiver assisting the sessions in order to guarantee the correct handling of technical equipment, the explanation of game content, how to solve tasks or when physical assistance is required. An introductory session where the SG and equipment is explained in general might be wise to give PwD a first insight into what they will engage in and to prevent overload in the first game session.

Recommendations

- Instructions should be kept brief and concise.
- It is recommended that a caregiver gives instructions on how to use technical equipment, on game content and on how to solve game tasks.
- Introductory sessions are recommended where handling of technical equipment and games are practiced exemplary.

2.4. Game content and cognitive and motor requirements

Ten studies featured cognitive game contents, such as exploring homepages (e.g. BBC news, National Geographic) and interacting with applications (e.g. Google Earth or Google Maps), answering multiple choice questions, performing IADL (shopping, cooking, writing and sending E-Mails, money management), playing virtual instruments, solitaire or block-match and solving navigation (e.g. walking through a park) and memory tasks (18,20,23,24,27–32). Cognitive requirements comprised, for example, visuo-spatial analysis, spatio-temporal orientation, attentional monitoring, divided attention, problem solving, action planning, reminiscence/memory skills, reading, recognition, concentration, imagination, shifting, inhibition, navigation and timing.

Six studies featured motor game contents, such as Nintendo Wii Bowling®, Nintendo Wii Tennis®, (Nintendo Wii®) Balance or Nintendo Wii Golf®, apple box lifting, fruit sorting and boat rowing (20–22,36–38). Motor requirements comprised, for example, fine motor skills, movement of limbs, balance, aiming, psychomotor skills (e.g. (hand-eye) coordination), postural control, weight shifting, lateral stepping, reaching beyond one's arm length, bending, tilting and upper body and head rotation.

Six studies featured motor-cognitive contents, such as cycling, snowboarding, juggling, car racing, coin grabbing or scratching bubbles (19,20,33–35,39). Motor-cognitive requirements comprised mostly dual-tasking. One study applied a stationary bike connected to a screen where PwD cycled while popping blue and yellow balloons on the screen by pressing the corresponding buttons on the steer (39). One study asked PwD to move the cursor from the center of the screen to the highlighted yellow balls as fast as possible by shifting their weight while they were standing on a platform with swivel joints (35). One study instructed PwD to move their legs to music by tapping on a mat right in the moment when two virtual balls, falling from the top of the screen, hit the drums on the bottom of the screen (34). In another study where PwD had to scratch virtual bubbles moving through a big screen through gesture control, PwD also had to use their attention skills since they were only allowed to scratch blue bubbles but had to spare the red ones. In order to scratch the bubbles, they had to move and coordinate their upper limbs in space (19).

Each SG requires some kind of dual- or multi-tasking abilities. Games that train cognitive skills through PC activities do also require fine motor skills when handling the keyboard and the mouse or the touch pad. The one study that had the players play familiar songs on a virtual keyboard required several skills at a time: (1) holding and moving the Wiimote, (2) aiming (the cursor on the highlighted key), (3) pressing the button on the Wiimote (to enter the highlighted key and make the system play the corresponding note) and (3) reading and singing (the song lyrics) (18).

The virtual instrument-study reported that the multi-tasking requirements were often too challenging for PwD so that the caregiver did most of the Wiimote handling or that tasks were split between players ("I play, you sing" dynamic) (18). Studies that applied the commercially available (and not modified) Nintendo Wii Sports® games reported that PwD needed assistance from the caregivers since they were overwhelmed by handling the Wiimote and performing the motor tasks at the same time (22,37). PwD had to face different challenges simultaneously. While remembering how to control the Wiimote (buttons and their different functions) and when to push and release the trigger, they had to coordinate and time their movements.

Furthermore, one study reported that the posture for playing the games may not generally be suitable for PwD as they get

easily fatigued, might suffer from hand tremor (what makes it difficult to hold and control the Wiimote) and other physical pain (37). In order to include PwD that get easily fatigued or have distinct balance problems, it may be considerable to create motor games that can either be performed while standing or seated.

Personal work experience and existing literature have shown that it is wise to create game contents that matches activities and interests of PwD and to personalize game content (e.g. incorporating personal pictures) (30,36). Since they often show a defensive attitude towards unfamiliarity (18), games that relate to previous hobbies (e.g. dancing, singing, skiing, hiking) and activities (e.g. picking apples, gardening, cooking) seems adequate. With this, reminiscence to their past (e.g. childhood, teenager years or early adulthood) could be created and communication and social interaction between players could be initiated.

Recommendations

- Games should place their focus on either cognitive or motor skills in order to prevent overload. However, since SG will always require some kind of cognitive and motor skills simultaneously, it is recommended to not exceed dual-tasking, i.e. combining only ONE cognitive skill together with ONE motor skill.
- Game content should be personalized (e.g. through personal pictures) and match personal interests and previous hobbies or activities (e.g. dancing, hiking, gardening, cooking) to create a fun atmosphere.
- It is recommended that motor games should be designed in a way that they could be performed while standing or seated in order to include PwD that get easily physically fatigued or show balance problems.

2.5. Animations and game perspective

Two studies reported that they only had a minimum number of objects in the screen and tried to avoid crowded screens with unnecessary objects in the background (18,36). One study applying Nintendo Wii Bowling® and Nintendo Wii Tennis® reported that too many information were displayed on the screen (e.g. arrows and instructions to guide movements or game scores) (37). One study chose to have only one active screen area (i.e. highlighted with a colorful frame) at a time and designed large and highly contrasted icons (18). Three studies applying Nintendo Wii® games let PwD create their own game character (Mii character) that functioned as an avatar in games with third-person perspective (20,22,37). MobiAssist used either a male or a female avatar for playing games in third-person perspective. One study reported that they played SG in front of a green screen that projected PwD into the game scenario so that games could be played in first-person perspective (33).

PwD have a reduced attention span which makes it difficult for them to focus on a certain task (18). Thus, avoiding accessories and too many objects irrelevant for the game task seems right to prevent the player getting distracted from the actual game task. PwD also often show decision-making difficulties (18). To reduce the burden of making a choice what to interact with on the screen, only one active screen area could be a feasible approach. In order to support visual abilities of PwD, large and highly contrasted icons may compensate visual deficits. MobiAssist lacked large and highly contrasted pictures in their quiz games which made the players often remark "Oh, I cannot recognize what is in the picture there. Is it a crocodile? Is it a bunch of leaves?". This shows how important it is to integrate pictures and icons that PwD are able to clearly identify.

Regarding game perspective, one study reported that players were not able to recognize their own Mii character that they created as their avatar for the games (22). What I could observe with MobiAssist was the difficulty that PwD generally had when gaming with the avatar. Some needed repeated explanations in each session to understand that the avatar would simultaneously mimic the exact movements that they do in front of the screen. I tried to explain how playing with the avatar works by demonstrating movements in front of the screen such as lifting my arms and legs and asked the players to observe how the avatar mimics my movements. PwD may have a limited capability to think in such abstract way and to emphasize with artificial characters in a screen. To overcome the difficulty with the concept of playing with a third-person perspective, a first-person game perspective may be more suitable for PwD.

Recommendations

- Accessories should be avoided and only one help icon (e.g. arrow to point the direction where the player should be walking next) should be displayed at a time.
- Only one active screen area to interact with is recommended.
- Large and highly contrasted icons are recommended.
- Games should be played from a first person perspective to prevent confusion with avatars.
- It is recommended that motor games should be designed in a way that they could be performed while standing or seated in order to include PwD that get easily physically fatigued or show balance problems.

2.6. Task difficulty

Nine studies reported that they integrated different difficulty levels (18,19,23,24,29,31,33,35,39). Four of them had the levels set by the caregiver/research personnel according to the cognitive and motor abilities of the player (18,23,24,33). However, only one study provided concrete information on the rule according to which the caregivers/research personnel adjusted difficulty levels (23). This study considered a task as solved when no false-positive reaction occurred, when all targets were found and when no aid was given by the research personnel. If these requirements were

met, the researcher increased the difficulty level (23). One study reported that even though the difficulty level was adjustable by the caregiver/research personnel, only the easiest level was played. Otherwise it would have exceeded the players' abilities (33). Only two studies provided concrete information on how the SG was programmed to automatically increase difficulty (29,39). One of them increased difficulty when the response time was less than five seconds and the error rate was less than 5% (39). The other one increased difficulty after three consecutive performances without error or when a player completed 80% of the tasks correct over six sessions (29). This study decreased difficulty when performance fell below 15% correct in three consecutive sessions or below 20% in six consecutive sessions, respectively (29). MobiAssist included levels that were programmed to automatically increase when 80% of the required game performance was achieved.

Examples for how difficulty levels increased are following: In the study where PwD played a virtual keyboard, difficulty could be increased by adjusting the number of keys (between eight and eleven keys) (18). One study, where PwD played a virtual cooking game, increased the difficulty through an increase of the number of ingredients, planning of actions needed to cook a certain meal and the actual performance of gestures to accomplish tasks (31). Another study, where PwD had to perform a virtual Trail Making Test increased the difficulty by adding additional numbers (35). The study, where PwD had to scratch virtual blue bubbles, difficulty was increased by increasing the bubble movement speed (19).

Three studies reported the application of a concept called "errorless" learning and game play (18,24,34). It is "a technique that can compensate for neurocognitive deficits as they relate to acquisition of new skills and abilities" (24) and thus make failures impossible or unlikely to happen (18). As described in chapter **2. Feedback,** in the study where PwD played a song on a virtual keyboard, clicking on the wrong key resulted in reduced volume of the note played. The system did not count the wrong key as error and PwD could proceed playing along (18).

Studies have shown that there are two options of how to handle difficulty levels. First, the SG is programmed to adjust difficulty automatically and second, difficulty levels are set by caregivers. However, I believe that a combination of both might be wise. As I observed during my work with MobiAssist, cognitive and motor abilities of PwD can vary from day to day. It may happen that cognition and motor function worsen from one day to another but improves again the following day.

As described above, SG could be programmed to adjust difficulty when a certain percentage of correct game performance is achieved (e.g. increase when performance was 80% or decrease when performance was below 20% in six consecutive sessions). However, the SG should also provide the opportunity to adjust difficulty manually.

Caregivers work with their PwD each day. They can observe the cognitive and physical conditions daily and thus may have a greater expertise than a system to correctly estimate which level might be appropriate for the player.

Regarding errorless game play, this principle is supposed to counteract the fear of failing in PwD and to prevent them from giving up too easily when no immediate success was achieved as PwD show difficulty in self-correcting errors (18,24). However, this counteracts the purpose of giving feedback on game performance which is important to enhance learning strategies and which fosters social interaction and communication between players when comparing game scores (see **2.2. Feedback**). Compromising these two approaches, the SG should incorporate games where PwD can achieve early success without making too many errors and thus might become frustrated and lose motivation (24).

Recommendations

- SG should incorporate games where PwD can achieve early success to foster motivation and prevent frustration.
- SG should incorporate a programmed algorithm to automatically adjust difficulty levels (e.g. increase when performance was 80% or decrease when performance was below 20% in six consecutive sessions).
- SG should also provide the opportunity to manually adjust difficulty levels by caregivers depending on the player's current cognitive and physical condition of the day.

2.7. Setting

Two studies implemented the SG at home (30,31) and 17 at a research facility or nursing home/care unit (18–24,28,29,32–39). Fifteen studies reported that SG were played in a single setting (19,21–24,28–33,35–37,39). Four studies played the SG in groups of three to ten PwD (18,20,34,38). Those studies reported that professional caregivers were instructed to create a pleasant environment where players feel enjoyment by using praise and providing assistance with technical equipment or explaining instructions if necessary. They were encouraged to let group dynamics and social roles evolve. One study reported that caregivers asked PwD about their physiological and psychosocial needs (e.g. urination, hunger, pain, tiredness) before they started the game to guarantee incident-free game sessions (32). They also reported that implementing SG in a group setting resulted in mutual support between players. They found that social interaction and communication was fostered not only between players but also between players and caregivers. Studies reported that players exchanged affection and empathy for each other, involved in discussions, cheered, played doubles, commented on each other's performance, gave feedback and tips or even

explained instructions. This created a sense of empowerment, achievement and independence. Interacting and competing with other players provided the opportunity to challenge their own perceptions and abilities.

MobiAssist was mainly implemented at home for single use in the main study. The caregivers had to personally involve with the game so that they could set up each session (e.g. switching the game on and off) and help with the handling of the technical equipment. They had to explain the games and watch the session in case their assistance was required.

From my personal work experience with MobiAssist in the main study, I could observe that the SG placed an additional burden to the daily care responsibilities on the caregivers (which were mostly the PwD's spouse). Receiving a dementia diagnosis changes the whole life situation not only of the person affected, but especially of their significant other. With the diagnosis, the role of the significant other changes from being a partner to being a caregiver that is confronted with the cognitive and motor degeneration of their partner. They have to learn how to cope with behavioral changes and learn how to integrate care routines (e.g. grooming and feeding) in their daily life. This often results in psychological stress and caregivers tend to forget to spare some time for themselves because they fear leaving their PwD alone. They often tend to neglect their personal needs and put the needs of their PwD over their own well-being.

Facing all these significant changes is difficult enough. After the intervention period, caregivers often reported that little fights arouse during the games. Disagreements occurred over how to play games. Caregivers admitted that they were too impatient with their PwD when they did not understand or did not follow game instructions correctly or did not log in right answers in quiz games immediately. Thus, a neutral third person supervising the sessions might overcome the problem of the caregiver being in need of acting as "teacher" giving advice which could seem too bossy and which PwD might see as personal critique.

From my personal work with MobiAssist that I also played with a group of PwD in a daycare unit, I experienced that a rotating system where the active player role changed after each game was highly appreciated among the participants. I can highly confirm what other studies have found: mutual support between players occurred and social interaction and communication was fostered not only between players but also between players and myself. I can see a great advantage in providing SG for PwD in groups supervised by a professional caregiver. Not only that social competence of PwD are triggered, but also the additional burden for their spouses investing time and their patience would become no longer necessary. Instead, they could take the time, when PwD are playing SG in a group, trying to relax and engage in activities that otherwise get neglected in their everyday life and thus create a healthy balance between care responsibilities and personal interests.

Recommendations

- It is recommended to play SG in groups supervised by professional caregivers, e.g. in a common room of a nursing home or daycare facility, to assist PwD with technical equipment and to create a pleasant environment where social interaction and communication as well as group dynamics can evolve.
- It is recommended to implement SG in a group setting of not more than ten participants to ensure that each participant has the chance to engage in the SG equally.

2.8. Schedule

In eleven studies sessions lasted between 20 and 60 minutes (19,21–24,27–29,36,37,39). Two studies reported sessions took up to 120 minutes per session (20,38). Sessions were held between once (20,22,34,37) to five times per week (23,32,33,36). Regarding physical activity engagement, the WHO recommends 150 minutes of moderate-intensity activity in bouts of at least ten minutes duration throughout the week for adults of 65 years and above (25).

Since PwD face cognitive and motor impairments (e.g. reduced attention span, gait disturbances) (1,18), it might be worthwhile to create relatively short games (e.g. around five minutes) and to see SG as one component in the activity plan of PwD and not as the only source of physical activity engagement. In MobiAssist, PwD played a game where they walked through a park by lifting their feet in place (in higher levels, game time was over ten minutes) but felt bored and exhausted after five minutes. Even though the World Health Organization recommends physical activity in ten minutes bouts (25), it would not be beneficial to create games that PwD are not willing to engage in. Designing shorter games that keep PwD interested and motivated would be more useful as one could imagine that PwD would play those games more often and thus accumulate the recommended physical activity amount. From my personal work with MobiAssist in a daycare unit, I experienced that playing 45 to 60 minutes sessions twice a week was highly appreciated among the participants and easy to integrate in the daycare routines of the facility.

Recommendations

- SG should not be seen as the only source of (physical) activity for PwD.
- Sessions of 45 to 60 minutes twice a week seem to be manageable for both PwD and the care management plan of nursing homes or daycare facilities.

3. Discussion

Summing up, our main recommendations on the design of SG for PwD are:

- Use large, well-contrasting icons. Display the game from a first-person perspective.
- Implement gesture control rather than remote control, keyboard, joystick or mouse.
- Keep cognitive requirements to a minimum, and adjust difficulty levels depending on the player's current cognitive and physical condition.
- If dual-tasking is to be trained, combine only ONE cognitive skill with ONE motor skill.
- Personalize game content to match players' interests, hobbies or other activities. Create a fun atmosphere.
- Design SG as a group activity, to be supervised by professional caregivers. Keep in mind that in nursing homes, game sessions must flexibly adapt to the care plan and to the availability of caregivers.

Below, a greater body of independent evidence that supports our recommendations is listed:

One article found that VR-based SG are more efficient than tablet-based gaming (40). This would support our first recommendation of implementing natural movements over keyboards in order to execute game tasks. Another article found that the permanent provision of real time guidance and the reduction of information on the interface are key to successful SG design (41). These suggestions would also support our recommendations of giving immediate feedback and reducing accessories on the screen. A group of researchers designed a SG by creating an environment that is well-known to the player with familiar challenges (42). This would support our recommendation that the SG content should be as personalized as possible. Further, they applied a strategy where the game was "capable of estimating the cognitive abilities of the patients through the play sessions, using the data collected from the different activities" (42). This goes along with our recommendation of programming an algorithm that automatically adjusts difficulty levels to adapt to the player's abilities and to guarantee an early success so that motivation is fostered. One research team found that the combination of physical and cognitive training promises greater cognitive benefits than physical training or cognitive training alone (43). This supports our recommendation to combine one cognitive with one motor requirement. However, we would like to emphasize once more that combining more than one cognitive and one motor requirements may exceed the capacities of PwD and thus cause frustration and demotivation. One article supports our recommendation that SG should ideally be implemented in a group setting (44). The article reported that group interventions enhanced not only memory performance, but also an enhanced well-being through engaging in shared social activity in residents of (i.e. dementia) care units (44). Two researchers collected tips on how to effectively communicate with PwD (45). They emphasized using "short and simple sentences" as well as speaking slowly in a simple language (45). Further, they stresses that "effective communication can make to patients' wellbeing and quality of life" (45). Their tips underpin our recommendations on the design of SG instruction: keeping them brief and concise in the presence of a caregiver. The Cochrane Review of 2013 reported that the length of intervention sessions for exercise programs in PwD between 20 and 75 minutes (13). Here, the evidence remains still unclear what may be the ideal session length. However, we would like to highlight that, depending on the care management plan of nursing homes and daycare facilities, 45min sessions twice a week seem an adequate amount of SG training time.

One limitation of the present paper is the sparseness of pertinent literature: we could retrieve 20 articles on SG training for PwD, but each addressed only one or a few of the eight SG characteristics covered in the present paper. Furthermore, some of those articles did not specify in their Results and Discussion sections whether procedures were indeed as feasible as anticipated in their Methods sections. Another limitation is that some recommendations are based on personal work experience with one particular SG, MobiAssist, and therefore may be biased. However, we would like to emphasize that personal work experience rather upgrades the value of the given recommendations as the inclusion of first-hand experience adds to the theoretical knowledge drawn from the literature.

The given recommendations are a novelty. They are unique and explicitly written for the target group of PwD. They represent a concrete and profound step-by-step guidance in not only how to design, but also how to implement serious games. Our recommendations thus add to already existing and more general standard human-computer interaction textbooks (46,47) and other scientific work in the field (16,48).

The present paper is supposed to present the starting point for future empirical studies that implement our recommendations. In Appendix 1, we present an example of a likely application of the recommendations in a future serious gaming project covering the training of spatial navigation skills in PwD.

Appendix 1 presents the recommendations to enhance the usability of one specific SG for PwD. Inspired by VR city, we decided to consider a SG for the training of spatial navigation skills in PwD.

Appendix A. Guidelines for the design of a serious game for spatial navigation training in people with dementia.

Background. Spatial navigation is the "ability to maintain a sense of direction and location while moving about in the environment" [39]. This ability deteriorates in older age [40]. PwD are affected already in the early stages of their disease [41].

Input and output device. A virtual environment is displayed on a set of large TV screens. Players move forward through this environment by walking in place, and turn left- or rightwards by lifting their left or right arm.

Feedback. When a player successfully completes a navigation task, i.e., when they reach the instructed destination (see below), they receive encouraging visual and/or auditory feedback, depending on their sensory abilities. If the destination is a store, players select a virtual item from that store and receive the pertinent real item as a reward. A summary screen provides a list of tasks completed so far, along with a one-to-five star rating.

Instructions and assistance. A caregiver explains and demonstrates all game features that are relevant for game use, not more and not less. This includes what is displayed, what kind of tasks will be presented, how to move through the virtual environment and how to interpret summary screens. If players hesitate along their way or take a wrong turn, conspicuous high-contrast arrows appear on the screen for guidance.

Game content and requirements. The virtual environment displays a familiar neighborhood with familiar landmarks. Tasks are to walk from a "home" position to a specified landmark (i.e., acquisition of route knowledge), to find new shortcuts between landmarks (i.e., acquisition of survey knowledge), and to complete either of those tasks along with a concurrent, realistic task (avoiding collisions with virtual oncoming pedestrians, crossing a busy street, remembering a shopping list, etc.).

Animations and game perspective. Realistic animated objects (trees blowing in the wind, domestic animals on the sidewalk, pedestrians, cars, …) are introduced in dependence on each player's momentary capacity to deal with distracting events. Players navigate through the environment in a first person perspective.

Task difficulty. Adaptive modification of task difficulty, starting with a walk towards an always-visible landmark in a stationary environment with a simple architecture, up to a walk towards one of many landmarks in a complex environment with multiple stationary and moving, realistic distractors.

Setting. Common room of a nursing home or daycare facility. A caregiver supervises the game session and facilitates social interaction. They ensure that participants take turns as active players and encourages the other participants to provide hints and encouraging feedback.

Schedule. Game sessions of 45 minutes, twice per week.

References

[1] World Health Organization. Dementia [Internet]. World Health Organization; 2017 [cited 2019 Jan 25]. Available from: https://www.who.int/news-room/fact-sheets/detail/dementia.

[2] World Health Organization. 10 Facts on Dementia [Internet]. World Health Organization; 2015 [cited 2016 May 3]. Available from: http://www.who.int/features/factfiles/dementia/en/.

[3] Zidan M, Arcoverde C, Araújo NBd, Vasques P, Rios A, Laks J, et al. Alterações motoras e funcionais em diferentes estágios da doença de Alzheimer. Rev Psiquiatr Clín. 2012;39(5):161–5. doi: 10.1590/S0101-60832012000500003.

[4] Neugroschl J. Agitation. How to manage behavior disturbances in the older patient with dementia. Geriatrics. 2002;57(4):33-7; quiz 40. PubMed PMID: 11974389.

[5] Reisberg B, Ferris SH, Leon MJ de, Crook T. The global deterioration scale for assessment of primary degenerative dementia. Am J Psychiatry. 1982;139:1136–9. doi: 10.1176/ajp.139.9.1136.

[6] World Health Organization. The top 10 causes of death [Internet]; 2018 [cited 2019 Jan 2]. Available from: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death.

[7] Prince M, Wimo A, Guerchet M, Ali G-C, Wu Y-T, Prina M, editors. World Alzheimer Report 2015: The Global Impact of Dementia. An Analysis of Prevalence, Incidence, Cost and Trends. London; 2015.

[8] World Heart Federation. The costs of CVD [Internet]; 2019 [cited 2019 Feb 2]. Available from: http://www.championadvocates.org/en/champion-advocates-programme/the-costs-of-cvd.

[9] Ströhle A, Schmidt DK, Schultz F, Fricke N, Staden T, Hellweg R, et al. Drug and Exercise Treatment of Alzheimer Disease and Mild Cognitive Impairment: A Systematic Review and Meta-Analysis of Effects on Cognition in Randomized Controlled Trials. Am J Geriatr Psychiatry. 2015;23(12):1234–49. doi: 10.1016/j.jagp.2015.07.007. PubMed PMID: 26601726.

[10] Bahar-Fuchs A, Clare L, Woods B. Cognitive training and cognitive rehabilitation for persons with mild to moderate dementia of the Alzheimer's or vascular type: a review. Alzheimers Res Ther. 2013;5(4):35. doi: 10.1186/alzrt189. PubMed PMID: 23924584.

[11] Sitzer DI, Twamley EW, Jeste DV. Cognitive training in Alzheimer's disease: a meta-analysis of the literature. Acta Psychiatr Scand. 2006;114(2):75–90. doi: 10.1111/j.1600-0447.2006.00789.x. PubMed PMID: 16836595.

[12] Blankevoort CG, van Heuvelen, Marieke J G, Boersma F, Luning H, Jong J de, Scherder EJA. Review of effects of physical activity on strength, balance, mobility and ADL performance in elderly subjects with dementia. Dement Geriatr Cogn Disord. 2010;30(5):392–402. doi: 10.1159/000321357. PubMed PMID: 20980758.

[13] Forbes D, Thiessen EJ, Blake CM, Forbes SC, Forbes S. Exercise programs for people with dementia. Cochrane Database Syst Rev. 2013;12:CD006489. doi: 10.1002/14651858.CD006489.pub3. PubMed PMID: 24302466.

[14] Laamarti F, Eid M, El Saddik A. An Overview of Serious Games. International Journal of Computer Games Technology. 2014:1–15. doi: 10.1155/2014/358152.

[15] Sawyer B. The "Serious Game" Landscape. Instructional & Research Technology Symposium for Arts. Camden, USA; 2007.

[16] Robert PH, König A, Amieva H, Andrieu S, Bremond F, Bullock R, et al. Recommendations for the use of Serious Games in people with Alzheimer's Disease, related disorders and frailty. Front Aging Neurosci. 2014;6:54. doi: 10.3389/fnagi.2014.00054. PubMed PMID: 24715864.

[17] Dietlein C, Eichberg S, Fleiner T, Zijlstra W. Feasibility and effects of serious games for people with dementia: A systematic review and recommendations for future research. Gerontechnology. 2018;17(1):1–17. doi: 10.4017/gt.2018.17.1.001.00.

[18] Benveniste S, Jouvelot P, Péquignot R. The MINWii Project: Renarcissization of Patients Suffering from Alzheimer's Disease Through Video Game-Based Music Therapy. Entertainment Computing. 2010;6243:79–90. doi: 10.1007/978-3-642-15399-0.

[19] Colombo M, Marelli E, Vaccaro R, Valle E, Colombaril S, Garolfi S, et al. Virtual reality for persons with dementia: An exergaming experience. Gerontechnology. 2012;11(2). doi: 10.4017/gt.2012.11.02.253.00.

[20] Cutler C, Hicks B, Innes A. Does Digital Gaming Enable Healthy Aging for Community-Dwelling People With Dementia? Games Cult. 2015;11(1-2):104–29. doi: 10.1177/1555412015600580.

[21] Padala KP, Padala PR, Malloy TR, Geske JA, Dubbert PM, Dennis RA, et al. Wii-fit for improving gait and balance in an assisted living facility: a pilot study. J Aging Res. 2012;2012:597573. doi: 10.1155/2012/597573. PubMed PMID: 22745909.

[22] Fenney A, Lee TD. Exploring Spared Capacity in Persons With Dementia: What Wii Can Learn. Act Adapt Aging. 2010;34(4):303–13. doi: 10.1080/01924788.2010.525736.

[23] Schreiber M. Potential of an Interactive Computer-based Training in the Rehabilitation of Dementia: An Initial Study. Neuropsychol Rehabil. 1999;9(2):155–67. doi: 10.1080/713755596.

[24] Lee GY, Yip CCK, Yu ECS, Man DWK. Evaluation of a computer-assisted errorless learning-based memory training program for patients with early Alzheimer's disease in Hong Kong: a pilot study. Clin Interv Aging. 2013;8:623–33. doi: 10.2147/CIA.S45726. PubMed PMID: 23766638.

[25] World Health Organization. Physical Activity and Older Adults: Recommended levels of physical activity for adults aged 65 and above [Internet]. World Health Organization [cited 2019 Feb 13]. Available from: https://www.who.int/dietphysicalactivity/factsheet_olderadults/en/.

[26] MobiAssist. Mobilisierungsassistent für Menschen mit Demenz und deren Angehörige [Internet]. Available from: http://mobiassist.info/.

[27] Galante E, Venturini G, Fiaccadori C. Computer-based cognitive intervention for dementia: preliminary results of a randomized clinical trial. G Ital Med Lav Ergon. 2007;29(3):B26-B32.

[28] Talassi E, Guerreschi M, Feriani M, Fedi V, Bianchetti A, Trabucchi M. Effectiveness of a cognitive rehabilitation program in mild dementia (MD) and mild cognitive impairment (MCI): a case control study. Arch Gerontol Geriatr. 2007;44 Suppl 1:391–9. doi: 10.1016/j.archger.2007.01.055. PubMed PMID: 17317481.

[29] Tárraga L, Boada M, Modinos G, Espinosa A, Diego S, Morera A, et al. A randomised pilot study to assess the

efficacy of an interactive, multimedia tool of cognitive stimulation in Alzheimer's disease. J Neurol Neurosurg Psychiatry. 2006;77(10):1116–21. doi: 10.1136/jnnp.2005.086074. PubMed PMID: 16820420.

[30] Hoffman, M., Hock, C., Kühler, A., Müller-Spahn, F. Interactive computer-based cognitive training in patients with Alzheimer's Disease. J Psychiatr Res. 1996;30(6):493–501.

[31] Manera V, Chapoulie E, Bourgeois J, Guerchouche R, David R, Ondrej J, et al. A Feasibility Study with Image-Based Rendered Virtual Reality in Patients with Mild Cognitive Impairment and Dementia. PLoS ONE. 2016;11(3):e0151487. doi: 10.1371/journal.pone.0151487. PubMed PMID: 26990298.

[32] Tak SH, Zhang H, Patel H, Hong SH. Computer Activities for Persons With Dementia. Gerontologist. 2015;55 Suppl 1:9. doi: 10.1093/geront/gnv003. PubMed PMID: 26055780.

[33] McEwen D, Taillon-Hobson A, Bilodeau M, Sveistrup H, Finestone H. Two-week virtual reality training for dementia: Single case feasibility study. J Rehabil Res Dev. 2014;51(7):1069–76. doi: 10.1682/JRRD.2013.10.0231. PubMed PMID: 25437527.

[34] Yamaguchi H, Maki Y, Takahashi K. Rehabilitation for dementia using enjoyable video-sports games. Int Psychogeriatr. 2011;23(4):674–6. doi: 10.1017/S1041610210001912. PubMed PMID: 20880429.

[35] Wiloth S, Werner C, Lemke NC, Bauer J, Hauer K. Motor-cognitive effects of a computerized game-based training method in people with dementia: A randomized controlled trial. Aging Ment Health. 2017:1–12. doi: 10.1080/13607863.2017.1348472. PubMed PMID: 28682124.

[36] Eisapour M, Cao S, Domenicucci L, Boger J. Virtual Reality Exergames for People Living with Dementia Based on Exercise Therapy Best Practices. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2018;62(1):528–32. doi: 10.1177/1541931218621120.

[37] Legouverneur G, Pino M, Boulay M, Rigaud A-S. Wii sports, a usability study with MCI and Alzheimer's patients. Alzheimers Dement. 2011;7(4):S500-S501. doi: 10.1016/j.jalz.2011.05.2398.

[38] Tobiasson H. Physical action gaming and fun as a tool within elderly care - Game over or play it again and again… In: IEA '09, editor. Proceedings of the International Ergonomics Association 2009 conference; 2009.

[39] Karssemeijer EGA, Aaronson JA, Bossers WJ, Smits T, Olde Rikkert MGM, Kessels RPC. Positive effects of combined cognitive and physical exercise training on cognitive function in older adults with mild cognitive impairment or dementia: A meta-analysis. Ageing Res Rev. 2017;40:75–83. doi: 10.1016/j.arr.2017.09.003. PubMed PMID: 28912076.

[40] Aksoy E. Comparing the Effects on Learning Outcomes of Tablet-Based and Virtual Reality-Based Serious Gaming Modules for Basic Life Support Training: Randomized Trial. JMIR Serious Games. 2019;7(2):e13442. doi: 10.2196/13442. PubMed PMID: 31042153.

[41] Ben-Sadoun G, Manera V, Alvarez J, Sacco G, Robert P. Recommendations for the Design of Serious Games in Neurodegenerative Diseases. Front Aging Neurosci. 2018;10:13. doi: 10.3389/fnagi.2018.00013. PubMed

PMID: 29456501; PubMed Central PMCID: PMC5801308.

[42] Imbeault F, Bouchard B, Bouzouane A. Serious games in cognitive training for Alzheimer's patients. In: Staff I, editor. 2011 IEEE 1st International Conference on Serious Games and Applications for Health. 2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH); 11/16/2011 - 11/18/2011; Braga, Portugal. [Place of publication not identified]: IEEE; 2011. p. 1–8.

[43] Anderson-Hanley C, Maloney M, Barcelos N, Striegnitz K, Kramer A. Neuropsychological Benefits of Neuro-Exergaming for Older Adults: A Pilot Study of an Interactive Physical and Cognitive Exercise System (iPACES). J Aging Phys Act. 2017;25(1):73–83. doi: 10.1123/japa.2015-0261. PubMed PMID: 27337738.

[44] Haslam C, Haslam SA, Jetten J, Bevins A, Ravenscroft S, Tonks J. The social treatment: the benefits of group interventions in residential care settings. Psychol Aging. 2010;25(1):157–67. doi: 10.1037/a0018256. PubMed PMID: 20230136.

[45] Jootun D, McGhee G. Effective communication with people who have dementia. Nurs Stand. 2011;25(25):40-6; quiz 47. doi: 10.7748/ns2011.02.25.25.40.c8347. PubMed PMID: 21469475.

[46] Dix A, Finlay J, Abowd, Gregory, D.: Beale, Russell. Human-computer interaction. 3rd ed. Harlow: Pearson Prentice-Hall; 2004. 834 p.

[47] Preece J, Rogers Y, Sharp H. Interaction design: Beyond human-computer interaction. Chichester: Wiley; 2015. 567 p.

[48] McCallum S, Boletsis C. Dementia Games: A Literature Review of Dementia-Related Serious Games. In: Ma M, editor. Serious games development and applications: 4th international conference, SGDA 2013, Trondheim, Norway, September 25-27 2013 : proceedings / Minhua Ma [and three others] (eds.). LNCS sublibrary. SL 6, Image processing, computer vision, pattern recognition and graphics. Vol 8101. Heidelberg: Springer; 2013. p. 15–27.

[49] Wolbers T, Hegarty M. What determines our navigational abilities? Trends Cogn Sci. 2010;14(3):138–46. doi: 10.1016/j.tics.2010.01.001. PubMed PMID: 20138795.

[50] Parizkova M, Lerch O, Moffat SD, Andel R, Mazancova AF, Nedelska Z, et al. The effect of Alzheimer's disease on spatial navigation strategies. Neurobiol Aging. 2018;64:107–15. doi: 10.1016/j.neurobiolaging.2017.12.019. PubMed PMID: 29358117.

[51] Hettinga M, Boer J de, Goldberg E, Moelaert F. Navigation for people with mild dementia. Stud Health Technol Inform. 2009;150:428–32. PubMed PMID: 19745347.