Dementia Games: A Literature Review of Dementia-Related Serious Games

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Abstract. Serious games find wide application in the health domain, occupying their own place in the video game industry (games for health). Currently, there is a proliferation of cognitive training, exercise and social games, targeting one of the most dangerous disease of the era: dementia, as well as its various symptoms and stages like Mild Cognitive Impairment (MCI) and Alzheimer's disease (AD). However, the dementia-related gaming field is still uncharted. In this literature review, we list studies on serious games related to dementia, that are supported by evaluation tests on dementia, MCI and AD patients with published, peer-reviewed results. This review discusses the effects that games, which include Wii Fit, Wii Sports, Big Brain Academy, Lumosity, SmartBrain Games, MasterQuiz, MINDs et al., have on dementia-related conditions. The review leads us to the conclusions that, firstly, even though many games were developed for entertainment purposes, they are being used for health reasons (usually after technical or conceptual modification), acquiring the characteristics of serious games and, secondly, dementia games do have an effect on cognitive impaired people. If that effect is longlasting and/or transferable to the daily activities is a matter of further scientific investigation.

Keywords: Alzheimer's disease; dementia; literature review; mild cognitive impairment; serious games;

1 Introduction

Dementia is one of the most significant problems facing social welfare systems [41, 31]. There are an estimated 35.6 million people with dementia worldwide. This number will nearly double every 20 years, to an estimated 65.7 million in 2030, and 115.4 million in 2050 [1].

The most common symptom or characteristic of dementia is impaired memory but it also results in impairments in thinking, communication, orientation, and coping with everyday tasks. Other symptoms are personality changes, anxiety, depression, suspiciousness, delusions and compulsive behaviours [41].

Dementia presents with various causes/types, the most common being Alzheimer's disease (AD) [34, 16, 10]. One of the early symptoms of AD is Mild Cognitive Impairment (MCI), a dementia-related heterogeneous clinical entity which

is associated with the transition phase from healthy ageing to dementia [36, 35, 44]. The progression from MCI to dementia appears to be time dependent, occurring primarily within the initial 18 months [8].

There have been a large number of studies documenting the use of serious video games with respect to cognitive, physical, and social abilities of the players [18, 27, 52, 30, 45, 33, 25, 32, 17]. Consequently, serious games find wide application in the health domain, occupying their own place in the video game industry: games for health.

Over the last few years, several video games, focused on various aspects and stages of dementia, have been developed. The main idea behind these games is to delay the health decline. The secondary objective is to both improve the living standards for these groups of users, by helping them to maintain their autonomy and their social relationships, and promote a relaxed state of mind [3]. Even though dementia is characterised as a cognitive impairment, both physical and social activities have been shown to delay cognitive decline and restore cognitive function [26, 23], particularly when combined with cognitive activities.

2 The motivation for a dementia-related games literature review

There are several serious games addressing various aspects of the dementia disease. Some of these games are specifically designed for addressing dementia-related issues (i.e. dementia, AD, and MCI et al.) and some others - even though they were developed with other purposes in mind (e.g. entertainment) - were found to offer better gaming experiences for patients and therefore have been adopted as serious gaming.

There is, currently, a proliferation of cognitive training, exercise and social games and yet the dementia subfield of games for health is uncharted. This review offers an overview of dementia-related serious games, supported by experimental studies. The intention of this review is to be useful for the many stakeholders related to the dementia disease. Doctors, caretakers and the public are interested in which games are available for fighting dementia and, generally, in acquiring a clearer picture of the preventative, rehabilitative and/or informative purposes that each game serves, in order to play them or suggestem them to patients. Moreover, game developers in the dementia-related field can utilise the following review as a guide, providing insight into the success or failure of specific game concepts, thus contributing to the development of more suitable, effective and high quality dementia games. Lastly, this review provides healthcare researchers with an overview of a selected part of the gaming field related to dementia, as well as the studies that evaluate these games, assisting them in their academic work, related either to games for health or tools fighting dementia.

3 Methodology

The methodology for developing the dementia games literature review can be summarized in two stages: 1) Scan the games which have been associated with general health and filter those to extract the dementia-related game titles. 2) Narrow these games down to the ones that present a documented, peer-reviewed, and published effect on dementia-related health issues. The motivation for the second stage is that we are dealing with a sensitive and serious health issue and the reviewed game titles have to be accompanied by credibility and validity.

The review of dementia games, presented in this study is research-driven and it focuses on various research studies of games related to dementia. Within the scope of this study, we examined publications evaluating the efficacy of serious games for dementia-related conditions. For a publication to pass stage 2, it has to be peer-reviewed, published and to examine the efficacy of a video game on dementia, MCI or Alzheimer's disease patients. We include a "games to be considered" section (Section 4.1), which includes games with promising potential but that lack studies supporting their effectiveness on players.

The reviewed publications were collected during November and December 2012 via a library database search, Google Scholar and Web of Knowledge search tools, scanning through academic databases including IEEE Xplore, ACM Digital Library, ScienceDirect, and Springer Link. The keywords used were ["dementia" or "mild cognitive impairment" or "Alzheimer"] and ["serious games" or "video games"]. Furthermore, the Google search engine was used to find commercially available cognitive training game titles.

4 Literature review of dementia-related serious games

The literature review of dementia-related serious games is presented in this chapter. Table 1 presents the games that are associated with the current literature review. A short description of each game is given and information about their distribution, their gaming platforms and the input methods they have. The "health game category" field utilises the categorisation scheme of McCallum [31], categorising games according to the health area they affect. McCallum in [31] categorizes games for health in: *games for physical health*, which promote physical fitness, *games for cognitive health*, which target cognitive improvement and stimulation, and *games for social/emotional health*, which encourage the players to link with their friends and enable the development of a sense of community.

In Table 2 the publications are presented and analysed based on several attributes. These are: the main objective of the study, the targeted health area, the type of the study, the size of the sample (N), the participants' health state and the duration of the study. The key findings of each publication are summarised in the last column of the table.

Table 1. The games of the dementia games' review.

Game Title	**Game description**	**Platform**	**Distribution**	**Health game category**	**Input method**	**Related studies**
WiiFit	An exercise game for the Wii console, with more than 40 activities and exercises, including strength training, aerobics, yoga and balance games [40].	Nintendo Wii	Commercial	Physical	Wiimote & movement	[42]
Wii Sports	A sports game by Nintendo, which is actually a collection of five sports simulations: tennis, baseball, bowling, golf, and boxing [39]	Nintendo Wii	Commercial	Physical	Wiimote & movement	[28, 13, 51, 50]
Big Brain Academy	A puzzle video game by Nintendo, testing the player's mental acuity in a five-category quiz: thinking, memorization, computation, analysis, and identification [37].	Nintendo Wii, Nintendo DS	Commercial	Cognitive	Wiimote & movement (Wii), Controller (DS)	[14]
Lumosity	An online brain training platform using personalized training to harness brain's neuroplasticity [29].	Computer, Mobile	Commercial	Cognitive	Type & click (Computer), Tap (Mobile)	[15, 11]
Posit Science	Cognitive training gaming software that effectively address cognitive issues related to healthy aging as well as a broad range of other conditions [43].	Computer	Commercial	Cognitive	Type & click	[2, 46]
Complete Brain Workout	A collection of braining training games by Oak Systems, with 40 activities to stimulate and exercise the brain in an entertaining way [12].	Computer	Commercial	Cognitive	Type & click	[48]
SmartBrain Games	A collection of brain training games by Educamigos, for youngsters, adults or seniors, to exercise the intellectual skills and to prevent their loss in a practical and entertaining manner [47].	Computer	Commercial	Cognitive	Type & click	[49]
MasterQuiz	A tablet-based reminiscence game for mild dementia patients. The core of the game is a quiz with an image displayed on the left and text-based answers on the right [31].	Tablet PC	Academic	Cognitive	Tap	[31]
Xavix Hot Plus	A collection of twenty-four physical/sport games, offering rehabilitation support to the elderly [53].	XaviXPORT console	Commercial	Physical	Controller & movement	[53]
MinWii (MINDs)	A serious video game targeting Alzheimer and demented patients, working as a simple music therapy tool, which allows the player to improvise or play predefined songs on a virtual keyboard [4].	Computer	Academic	Emotional	Wiimote & movement	[6]

Table 2. The literature review of dementia-related games

Game & Study	Targeted health area	Study type	N	Subjects' health state	Duration of study*	Objective of study	Key findings
WiiFit [42]	Gait & balance	Randomised pilot study	22	AD (mild)	5 sessions per week for 8 weeks	Determine the effects on balance and gait of a Wii Fit program compared to a walking program.	Wii Fit resulted in significant improvements in balance and gait comparable to those in the robust monitored walking program.
Wii Sports [28]	Motor skills & cognition	Usability study	N/A	AD (mild-to-moderate), MCI, healthy	1 introductory and 4 test sessions, 1 session per week	Determine the ability of older adults with cognitive impairment to learn to play Wii Sports games and to control their movements with the Wiimote.	There was improvement in performance measures for most of the participants and a number of usability problems for people with cognitive deficits.
Wii Sports [13]	Motor skills	N/A	3	Dementia	9-week training session & 5-6 month follow-up retention test	Probe the capacity of persons with dementia to learn motor tasks.	The patients demonstrated improvement in bowling scores and memory for procedural components of game participation that persisted up to 6 months.
Wii Sports [51]	Attention to task & positive affect	Multiple baseline study	2	MCI	3-4 sessions per week for 10 weeks, 3 follow-up sessions	Examine effects of Wii bowling on attention to task and positive affect of older adult women with MCI, compared to a television viewing phase.	Participants showed higher attention to task and high-level demonstration of positive affect while engaged in the interactive video game as compared to baseline.
Wii Sports [50]	Positive affect & motor skills	Pilot study	10	Dementia	100 gaming hours in 6 months	Investigate whether computer games such as Nintendo Wii Sports would support demented elderly, living in special housing, to enjoy moving physically and have fun.	Wii managed to bridge the gap between the various physical abilities of the players and the patients enjoyed the feeling of being more physically active, in the appropriate technological setting.
Big Brain Academy [14]	Cognition & behaviour	Randomised controlled trial	45	AD (mild)	12 weeks	Assess the efficacy of the Big Brain Academy compared to the Integrated Psychostimulation Program (IPP).	The group that played the game showed signicantly slower rates of cognitive decline and signicantly greater decrease in depressive symptoms, compared to the group using PPI and the control group.
Lumosity [15]	Cognition & mood	Pilot randomised controlled trial	25	MCI	30 sessions in an average of 11,43 weeks	Investigate the effects of cognitive training on memory functioning and whether the effects of training would generalise to non-trained neuropsychological measures.	Participants were able to improve their performance across a range of tasks with training, but there were no significant effects of training on self-reported everyday memory functioning or mood.

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Lumosity [11]	Cognition & physical exercise & psychology	N/A	78	MCI	12 weeks	Study the success of engaging patients with MCI in regular physical, social and cognitive activities by making the activities fun and easily accessible.	High activity completion rates were recorded and responses from participants have been overwhelmingly positive.
Posit Science [2]	Auditory processing speed & accuracy	Pilot randomised controlled trial	47	MCI	5 sessions per week for 6 weeks	Compare the effects of a formal computer-based, cognitive training program with more passive computer-based activities in older adults with MCI.	The results showed that intensive computer-based cognitive training is feasible in at least a subgroup of people with MCI.
Posit Science [46]	Neural substrates of response	Randomised pilot experiment	12	MCI	5 sessions per week, total of 24 sessions	Examining the influence of the software on memory ability and brain function in MCI patients by implementing exercises on processing speed and accuracy in auditory processing.	Cognitive training positively affected memory ability and memory-related left hippocampal function, even though the small number of participants did not lead to statistically signicant conclusions.
Complete Brain Workout [48]	Cognition	N/A	59	MCI	1 session per week for 6 months	Investigate the effectiveness of a computer based training on visual spatial abilities, visual attention, executive function and visual memory, in MCI patients.	Computer cognitive training helped the experimental group to improve attention abilities and the improvement was generalized in verbal memory and in ADL as well.
SmartBrain Games [49]	Cognition	Single-blind randomised pilot study	46	AD (mild)	24 weeks	To determine the usefulness of an interactive multimedia internet-based system (IMIS) for the cognitive stimulation of Alzheimers disease, compared to an integrated psychostimulation program (IPP) and cholinesterase inhibitors (ChEIs).	Although both the IPP and IMIS improved cognition in patients with Alzheimers disease, the IMIS program provided an improvement above and beyond that seen with IPP alone, which lasted for 24 weeks.
MasterQuiz [31]	Memory	Pilot usability study	N/A	Dementia (mild)	6 design cycles	Assess the level of independence of dementia patients while playing.	It was possible for the majority of the users to independently play a game on a mobile device and there were no problems with the user interface on the device.
Xavix Hot Plus [53]	Cognition	Interventional study	9	Dementia (mild-to-moderate)	1 session per week for 10 weeks	Improve residents cognitive function indirectly by enhancing motivation using enjoyable video-sports games in a group setting.	The result showed that the general cognitive function, the visuospatial and constructive function were improved and there was an overall behavioural improvement and, more specically, improvement over the sociability of the participants.
MinWii (MINDs) [6]	Behaviour, motor skills & memory	Pilot usability study	7	AD (mild-to-moderately severe)	1 training & 4 testing sessions, once per week in a period of 3 months	Stimulating the cognitive and physical abilities of the players and aiming to improve the patients' self-esteem by setting feasible goals in a high-rewarding game.	MINWii was found to foster positive interaction with the caregivers, elicit powerful reminiscence with even the most severely impaired patients, and the patients' physical disabilities did not prevent the proper use of the Wiimote Pistol.

**The gaming sessions and hours are presented on a "per participant" basis*

4.1 Dementia-related games to be considered

In this section, supplementarily to the literature review, we are going to cover those dementia-related games, which present promising potential, however they have not been evaluated by studies, testing their effectiveness on dementia-related patients.

The brain training game *Brain Age* by Nintendo [38] was developed based on the previous findings of the study of Kawashima et al. [24], which examined the effect of reading aloud and arithmetic calculation on elderly people diagnosed with dementia. Kawashima's team measured their cognitive status before and after a 6-months training with two widely used tests to diagnose dementia: the Mini-Mental State Examination (MMSE) and the Frontal Assessment Battery (FAB). People in the training group improved their FAB score, maintained their MMSE score and became more communicative and independent.

KiMentia is a Kinect-based Windows application, developed to help cognitive stimulation for individuals with dementia and presented in the study of Breton et al. [7]. The tool focuses on therapeutic aspects of both cognitive and physical stimulation by allowing the player to perform mental activities and physical exercise at the same time. Five experts (two physiotherapists and three psychologists) took part in a simple personal interview about the satisfaction coming from the use of Kimentia and the survey reported positive results.

Using the paradigm of a serious game as a therapeutic tool for dementia, the *eMotiva project* introduces a collection of cognitive games for dementia, attempting to stimulate different cognitive processes such as memory or attention, trying to keep the patient motivated at all times [3, 9].

Another serious game, specifically designed for treating dementia/Alzheimer patients is an *untitled cooking game*, proposed by Imbeault and Bouchard et al. [5, 21] where a prototype has been developed, taking advantage of artificial intelligence techniques to create an accessible tool for cognitive training and allowing in-game estimation of the patient's cognitive performance.

A recent development in the dementia gaming area is the educational game *Into D'mentia* by Ijsfontein. The game consists of a physical, interactive space where the world of a person with dementia is visualized using Virtual Reality and players are able to experience the limitations and obstacles that a dementia patient faces on his/her daily life [22]. The game uses a simulation platform and it takes place inside a specifically customised truck. The goal of the game is to stimulate empathy for people with dementia and to raise awareness for the difficulties faced by these people.

5 Discussion

Reviewing these studies shows notable findings. Firstly, an interesting point for dementia games is that many games, that are developed for entertaining purposes, are being used for health reasons. Some examples are the Nintendo's titles: Wii Fit, Wii Sports, and Big Brain Academy. These games are designed with a

Fig. 1. A brain training game about recognising cities, from SmartBrain Games.

"typical user" in mind [19, 20]. Even though, these games cannot fully fulfill the perceptual and interaction needs of people suffering from dementia-related diseases, they are widely used amongst the elderly and cognitive impaired patients [5].

In our literature review, we examined studies showing that physical games can positively affect several health areas of the players. Padala et al. in [42] used a relatively large number of participants (N=22) and had a high number and frequency of gaming sessions (5 sessions per week for 8 weeks/participant), showing that the dementia patients could benefit from WiiFit in acquiring better balance and gait, compared to a walking program. Since dementia heavily affects cognition there are attempts to address cognitive decline through physical games. The interventional 10-week study of Yamaguchi et al. [53], using the Xavix Hot Plus game managed to show that a certain improvement in general cognitive function is possible for mild-to-moderate dementia sufferers. The studies of Weybright et al. [51] and Tobiasson et al. [50] - despite being small in participants' size - they present an adequate duration of study, therefore their positive results, regarding the positive affect that Wii Sports causes to MCI and dementia sufferers, are an indication of the emotional benefits coming from the game. However, it would be useful to take into consideration that the cognitive impairment of dementia patients may sometimes stand in the way of playing a video game. Legouverneur et al. [28] found a number of usability problems, mostly controller-related, when dementia patients played Wii Sports.

The studies related to the dominant game category within the dementia field - i.e. the cognitive games - present promising results. More specifically, Big Brain Academy [14] performed better than the Integrated Psychostimulation Program (IPP) in slowing down the cognitive decline of the participants (N=45) in a 12-week study. Another study that stands out - and which agrees with the previous finding to some extent - is the one related with the SmartBrain Games (Fig. 1)

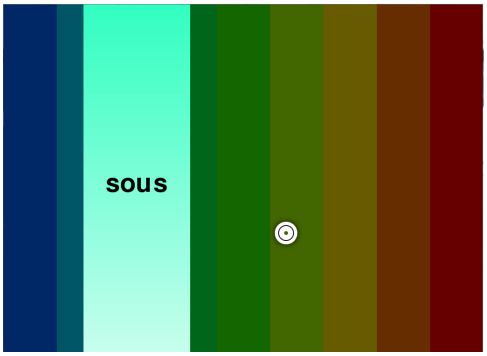

Fig. 2. The improvisation mode of the MinWii (MINDs) game, where players are invited to improvise, playing music by pointing at a virtual keyboard.

[49]. The study showed that the effect on cognitive improvement coming from playing the game exceeds the one coming from the Integrated Psychostimulation Program (IPP). Another notable finding is that this effect lasted for 24 weeks.

The current literature review of dementia games reveals a high concentration of game titles around the cognitive and physical functions of the players. However, the social/emotional function is less emphasised. MinWii (Fig. 2) is the only game in this study, having a direct, primary behavioural goal (improve patients' self-image), which was studied by Boulay et al. [6] and was found to foster positive interaction. The studies [11, 14, 50, 51, 53] showed that the games examined had positive results to the social/emotional state of the player - as side effects - affecting behaviour, depression, mood and sociability.

6 Conclusion & Future Work

Our work presents an overview of serious games for dementia and the relative studies on their efficacy. The main point that runs through our literature review is that dementia games do have an effect on cognitive impaired patients. Determining if that effect is longlasting and/or transferable to the daily activities is a matter of further scientific investigation.

During the course of this literature review, we analysed various health areas, health purposes, as well as engaged with various stakeholders, related to the dementia games' field. As a result of these interactions, we are developing a taxonomy of serious games for dementia, which will be presented in future publications.

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