Feasibility and effects of serious games for people with dementia: A systematic review and recommendations for future research

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Background and purpose: Over 40 million people worldwide are currently living with dementia. Physical activity is one treatment option for this target group and delays the occurrence of symptoms, such as forgetfulness or disorientation. So far, it is unclear whether integrating serious games, which combine multimedia, entertainment, and training, into dementia therapy can bring additional benefits. The aim of this paper is to identify the available studies and to analyze the feasibility and effectiveness of serious games for people with dementia. Based on a systematic evaluation of studies, the paper tries to present recommendations for future research. **Methods:** A systematic literature search was conducted in various databases using key words related to dementia, serious games, and different outcome domains (i.e. cognitive and physical functioning, and personal/behavioral aspects). After screening titles, abstracts and full-texts, studies meeting the inclusion criteria were analyzed with regard to feasibility, effectiveness, and study quality. **Results:** Out of 11.198 potentially relevant studies, 11 studies were included in the analysis. Feasibility analysis showed that serious games should be played under the supervision and in groups in order to support understanding and handling of the technology, to foster social interaction and adherence to the program. Overall, serious games were found to be safe. Six studies with a controlled study design were available for analyzing effectiveness. These studies were of low methodological quality and represented a wide variety of intervention and assessment approaches. Four studies showed that serious games improved cognition, and in one study physical performance improved equally in intervention and control group. An added benefit of serious gaming compared to traditional interventions could not be identified. **Conclusion:** Serious games seem feasible in people with dementia. However, due to the limited number of available studies, the low methodological quality and a large heterogeneity of studies the overall effectiveness of serious games for people with dementia is unclear. Further research with solid study designs combining supervised group-based serious gaming and traditional therapist-led interventions is recommended.

Keywords: Alzheimer's disease, dementia, serious games, computer-assisted

Introduction

Improved health care in the past century has led not only to longer and healthier lives but also to an increased number of people living with non-communicable diseases such as dementia[1]. Dementia, a chronic and progressive syndrome that affects memory, thinking, motor functioning and social behavior, has become a serious public health issue. In 2015, an estimated number of 47.5 million people worldwide were living with dementia[2]. Experts project the numbers of dementia cases to reach 75.6 million by 2030 and to more than triple by 2050 to 135.5 million people living with dementia[2].

"The essential feature of Dementia is impairment in short- and long-term memory, associated with impairment in abstract thinking, impaired judgment, other disturbances of higher cortical function, or personality change. The disturbance is severe enough to interfere significantly with work or usual social activities or relationships with others."[3]. The cognitive and psychosocial symptoms are progressive. At the late stage, the losses result, for example, in forgetting names of close relatives and extensive need for assistance with activities of daily living (ADL)[4,5].

Treatment options, such as drug treatment, cognitive training or physical activity, are available for people with dementia. Drug treatments showed no effect on cognition in MCI and only a small impact on Alzheimer's disease dementia[6]. Evidence for the effectiveness of cognitive training in people with dementia or at risk of dementia is also limited[7,8]. However, many studies have shown that aerobic, strength and balance exercises can significantly delay the onset of symptoms and improve cognitive and physical functioning in patients with MCI and dementia[6,9]. An emerging intervention approach in the area of dementia therapy is serious gaming. Serious games use technology to combine three components which are multimedia, entertainment, and experience[10], and are defined as "games that do not have entertainment, enjoyment, or fun as their primary purpose"[11]. Serious games include computer games, training simulation and sports and board games[10]. The term "serious" indicates that the game is assumed to have effects on the player in the context of education, knowledge, training, skills, health or interpersonal communication[10]. Compared with traditional rehabilitation, serious games provide a low-cost alternative that can easily be installed in the user's home[12], which allows users to train whenever they want. Practicing in a familiar environment where users feel comfortable and receive real-time feedback and performance analysis[12] may lead to an enhanced training frequency and efficacy. Although results from studies of serious games and MCI seem promising (positive emotions associated with the games, increased memory, and attention abilities)[13,14], many questions about the feasibility and effectiveness of serious games have not yet been answered, especially regarding people with dementia. Feasibility, which comprises aspects such as comprehensiveness, adherence, acceptance, or the occurrence of adverse events, is crucial for achieving any effects on cognition, physical performance and personal/behavioral aspects (e.g. quality of life (QoL) and mood).

Existing reviews on serious games and dementia are either not systematic and do not make a clear distinction between feasibility and effectiveness aspects[15], or focus only on effectiveness[16]. Hence, the aim of this paper is to identify the available studies and to systematically analyze the feasibility and effectiveness of serious games for people with dementia. Rather than focusing on game design, the focus of this review is on analyzing the implementation of serious games and the effects on cognition, physical performance (including ADL) and personal/behavioral aspects (including QoL and mood). Based on a systematic evaluation of studies, the paper attempts to determine whether serious games are feasible or effective, and which factors need to be considered when using serious games with people with dementia.

Methods

This systematic review was written in accordance with the PRISMA statement[17].

Search Strategy

Between February 16, 2016 and February 17, 2017, online databases and grey literature were searched for publications on serious games for people with dementia with no publication date limitations. Filters were set for language (German, English).

The following online databases were searched: Pubmed, Cochrane Database, Web of Science, and the German Clinical Trials Register. A search string with the following combined key words was applied: "(dementia OR Alzheimer) and (exergame OR video game OR serious game OR computer OR virtual reality OR interactive OR digital)". The rationale for the broad search strategy was to yield as many hits as possible for articles to be potentially included in this systematic review. Besides controlled and observational studies, reviews and meta-analyses were included in the search in order to extract relevant studies for a possible inclusion in this systematic review.

Potentially relevant studies were selected from the results of the search strategy by screening titles, then the abstracts of these studies were screened. If there was any uncertainty about selecting a study, the full-text paper was read in order to decide whether to include or exclude the study. All relevant reviews and meta-analyses yielded by the literature search were screened for their included studies in order to select further relevant studies for this systematic review. If a study included in one of the reviews and meta-analyses was considered relevant, its full-text was read for the decision of inclusion or exclusion. The whole search process is presented in a flow chart (*Figure 1*).

Inclusion Criteria and Study Selection

Inclusion criteria (IC) are listed below in *Table 1*. Beside the overall IC, studies were included if they met the IC for feasibility and/or for the effectiveness of serious games in people with dementia, which are also listed in *Table 1*. Since feasibility is a broadly used term that may encompass a large number of different criteria depending on the type study[18], we addressed several criteria of feasibility that match the purpose of this review as seen in *Table 1*. Detailed information about these criteria is presented in the next section.

Data Extraction and Analysis

Information on bibliographic details of study (authors, year), population (inclusion criteria, sample characteristics including number of participants, and, where available, dropouts, mean age and gender distribution), intervention (type of intervention, duration per session, frequency, total intervention period), instruments and main results were extracted from the included studies.

Feasibility Analysis

The feasibility of serious games for people with dementia was evaluated according to Mayring's approach for qualitative content analysis[19,20] based on the following pre-defined categories: (i) Comprehensibility/playability. How easily can instructions and the content and design of the games be understood? Is the target group able to handle the technique while playing? Is the target group mentally and physically able to play the games?

(ii) Adherence/commitment: How often and how long do participants play the games? Are dropouts reported?

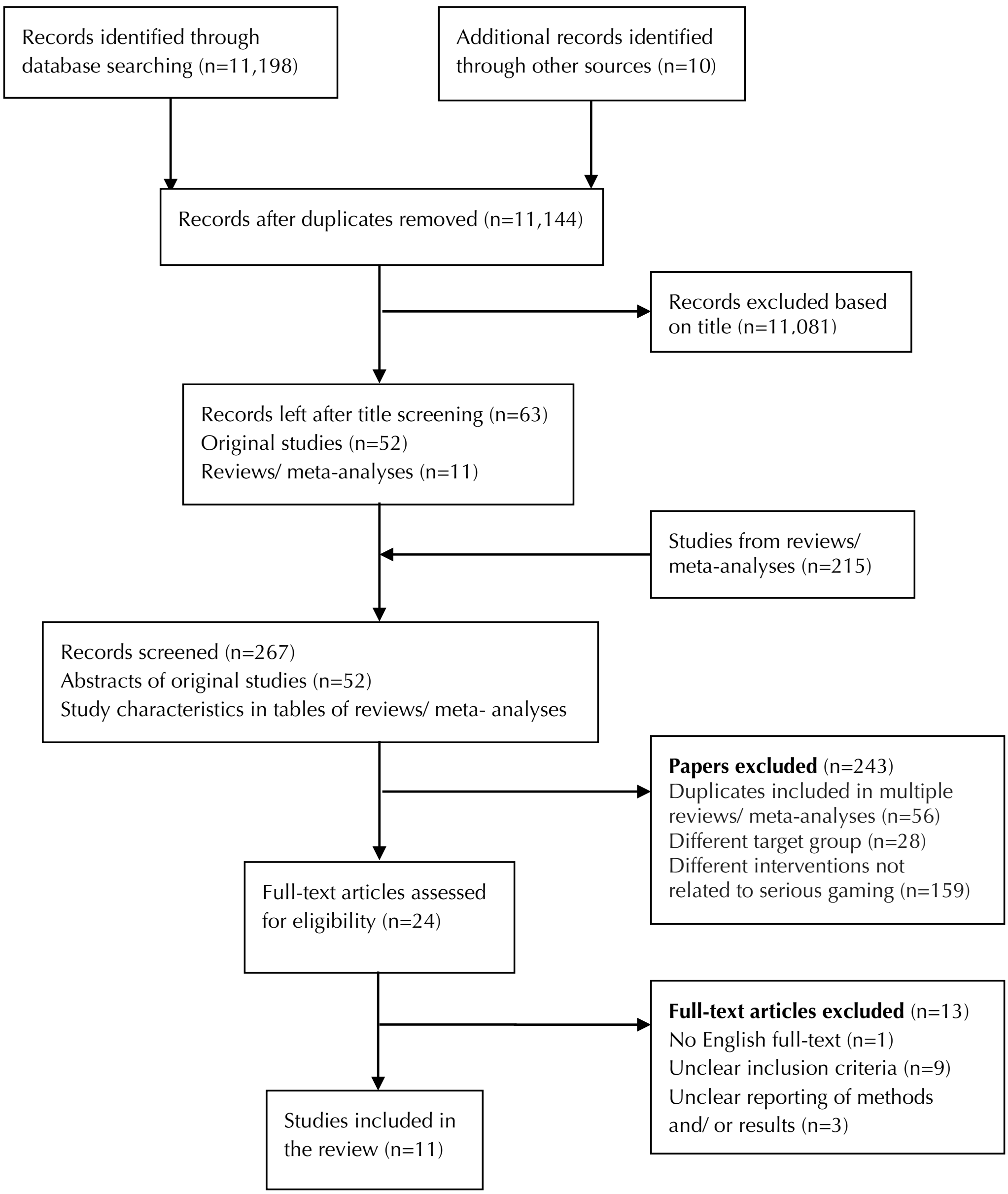

Figure 1. Flow chart of literature searched and study selection

Table 1. Inclusion criteria (IC) for studies in this systematic review

<table>
<tr><th colspan="2">General IC</th></tr>
<tr><td colspan="2">Study participants had a diagnosis of presumed dementia or a diagnosis of Alzheimer's disease together with a Mini Mental State Examination (MMSE) score of 25 or lower.
The intervention comprised of serious games.</td></tr>
<tr><th>Additional IC for feasibility analysis</th><th>Additional IC for effectiveness analysis</th></tr>
<tr><td>Study type: case study, observational study, (non-) controlled study

Feasibility criteria: comprehensibility, adherence, acceptance/enjoyment, adverse events</td><td>Study type: (randomized) controlled trial

Comparative intervention: any other intervention or passive control group (CG)

Outcome measures related to: cognition, physical performance (including balance, gait and ADL), personal/behavioral aspects (including QoL and mood)</td></tr>
</table>

(iii) Acceptance/enjoyment: To what extent and why do people living with dementia enjoy playing serious games? Why do they like the games? Why do they not like them?

(iv) Risks/safety issues: What kind of risks do the participants encounter with the games? Are there tripping hazards around? How great is the risk of falling or harming themselves when performing the games?

The full-text of each selected study was screened and relevant information (obtained through either observations or quantitative measures) was classified in the above mentioned categories.

Effectiveness Analysis
All available studies with a controlled design were selected to analyze effectiveness. Two independent raters (C.D. and S.E.) scored the methodological quality of the articles with a controlled design included in this systematic review using the checklist for the assessment of the methodological quality both of RCTs and NRS of health care interventions developed by Downs & Black[21]. The validated and reliable checklist comprises 27 items in five different domains, which are: reporting (item 1 – 10; max. score 11), external validity (item 11 – 13, max. score 3), internal validity/bias (item 14 – 20; max. score 7), internal validity/confounding (item 21 – 26; max. score 6) and power (item 27; max. score 5). For this systematic review, item 27 was not taken into consideration. Accordingly, the maximum score to be reached is 27, with a higher score indicating greater methodological quality[21]. The raters independently scored each item on the checklist. In the event of different scorings, they discussed the reasons for why they had chosen their particular score in order to compromise on a common quality score.

The effectiveness of serious games in dementia was evaluated based on the following outcome domains:
(i) Cognitive function: including e.g. attention, language, memory, orientation, verbal learning etc.;

(ii) Physical function: including balance, gait, and ADL;

(iii) Personal/behavioral aspects: including QoL and mood.

The full-text of studies with a controlled trial was screened and all relevant information was classified in the above mentioned effectiveness categories.

Results

Study Selection
The literature search revealed 11,198 potentially relevant studies. 10,877 hits could be excluded after title screening as they were out of scope (medication studies; interventions not related to serious gaming; completely different target group). After abstract screening and the screening of study characteristics tables in 11 reviews and meta-analyses, 24 articles remained for full-text screening. Finally, 11 studies were included in this systematic review (*Figure 1*).

General study characteristics
General study characteristics of the 11 included studies are summarized in *Table 2*.

Study Participants
Four studies recruited participants from clinics and hospitals[22–25], one from a long term special care unit[26,27], one from an assisted living facility[28], 2 from the local Alzheimer society[27,29] and 3 studies did not provide any information on recruitment[30–32]. Sample sizes ranged between one[30] and 66 participants[24]. Nine studies[23–25,27–32] reported the participants' age with a mean age between 6527 and 90 years[29]. The proportion of female participants ranged from 0% [29,30] to 85%[25,27]. One controlled study did not mention the participants' sex or age divided by groups[23]. Three studies did not report the participants' sex at all[22,26,31]. MMSE scores were reported in 8 studies[22–26,28,31,32] and ranged from 10 to 2522. Eight studies included participants with a diagnosis of dementia[23,24,26–30,32]. Three studies included participants with a diagnosis of Alzheimer's disease together with an MMSE score of 25 or lower[22,25,31].

Table 2. Study characteristics of included studies

Study	Study design	Subjects	Intervention	Instruments	Study quality
Benveniste et al. 2010	Non-controlled	Diagnosis of presumed AD Cognitive impairment (score between 10 and 25 at the MMSE) No profound deafness, blindness or motor disabilities Hospitalized in Geriatrics Unit of Hôpital Saint-Maurice (France) n=9	Video Game-Based Music Therapy (MINWii) Low cognitive and movement requirements, failure-free gameplay, simple design 9 virtual instruments could be played using a remote control: pointing on a virtual keyboard with colored keys Two modes available: improvisation mode (creating own songs) and challenge mode (playing familiar songs by clicking on highlighted keys) 1x/week, November 2009-February 2010	Observations, interviews	
Colombo et al. 2012	Non-controlled	Diagnosis of light to moderate dementia Cognitive impairment (score between 11 and 24 at the MMSE) Ability and will to engage with videogames Residing in Long Term Special Care Units n=10	Exergames (EyeToy for PlayStation 2) Increasing difficulty levels (different colors, speed of movement, bi-manual dexterity) Movements of the player detected by USB-camera placed on TV that reproduced person on the screen Blue and red bubbles floating over screen of which the blue ones had to be targeted and the red ones were not allowed to be scratched Up to 20 mins, 2x/week	Game records, observations	
Cutler et al. 2015	Non-controlled	Diagnosis of dementia Residing at own home together with caregiver or assisted living accommodation n=29 (♂ 11, ♀ 18), age = 65-80 years	Games on Nintendo DS, Nintendo Wii and Apple iPad Balance, art, cooking games Music/instrumental games Google Earth/Google Maps etc. Intervention (TC) delivered in 4 different venues where between 3 and 10 people participated 120 mins, 6-8 weeks Complete intervention period: September 2012- May 2014 with a total of 26 sessions	Field notes, self-complete questionnaires, focus groups	
Fenney & Lee 2010	Case Study	Diagnosis of dementia Part of the local Alzheimer Society concurrent day program for community-dwelling person with dementia n=3 (♂ 3, ♀ 0), age = 68, 79 and 90 years	Nintendo Wii Bowling Study participants played together with their peer groups of 2-4 players 60 mins, 1x/week, 9 weeks	Game records, observations	
Galante et al. 2007	RCT	Diagnosis of presumed AD according to NINCDS-ADRDA Mild cognitive impairment (score between 19 and 26 at the MMSE and between 70 and 90 at the MODA) Pharmacological treatment (AchE-I) n=12, ø age = 76.0 (±6.0) IG (Specific treatment with TNP): n=7 CG (Aspecific treatment): n=4	IG: TNP software on a touch-screen computer to stimulate cognitive function Assisted by a neuropsychologist CG: Cognitive activities supposed to balance the TNP intervention and a semi-structured interview on relevant events of life Assisted by a neuropsychologist	MMSE, MODA, Bisyllabic Word Repetition Test, Prose Memory, Corsi's Block-Tapping Test, Digit cancellation test, CPM, Verbal fluency (phonemic and semantic), Denomination, Constructional apraxia, Ideomotor apraxia (right and left limb), IADL, NPI, GDS	Reporting: 4 External validity: 0 Bias: 4 Confounding:0 Total: 8
Lee et al. 2013	RCT	Diagnosed AD (International Classification of Diseases 10th Revision or Diagnostic and Statistical Manual of Mental Disorders, 4th Edition) Early dementia (score of 1 on screening with CDR) 60 years and older n=24 (♂ 6, ♀ 13), ø age = 77.7 (±6.07) IG 1 (CELP): n=7; IG 2 (TELP): n=6; CG: n=6	IG1: CELP using a touch-screen notebook computer Serious games: face-name recognition, grocery shopping while cooking, taking the bus, categorization and counting of objects; Training of attention, working memory and focus on one memory training theme IG2: TELP identical to CELP in content and structure CG: General cognitively challenging activities, e.g. card sorting	MMSE, DRS, HKLLT, BAPM, MBI, HKLIADL, GDS Qualitative feedback	Reporting: 9 External validity: 0 Bias: 5 Confounding:0 Total: 17

Table 2. Continued

Author, year	Study design	Subjects	Intervention: Type	Intervention: Extent	Instruments	Study quality
McEwen et al. 2014	Single Case Study	Vascular dementia Cognitive impairment n=1 (♂) age = 78 Score of 12 at the Montreal Cognitive Assessment Daily medication Left visual field deficit Full ROM + strength	Virtual reality training program (interactive rehabilitation exercise IREX software) Progressive training (specific games for balance and functioning) Session split into 25mins of exercise time and 35mins of resting and explaining how to play upcoming game Sessions were held at the participant's home 60 mins, 5x/week, 2 weeks		Interviews with the caregiver, documentation of training events	
Galante et al. 2007	RCT	Diagnosis of presumed AD according to NINCDS-ADRDA Mild cognitive impairment (score between 19 and 26 at the MMSE and between 70 and 90 at the MODA) Pharmacological treatment (AchE-I)	n=12 ø age = 76.0 (±6.0)		MMSE, MODA, Bisyllabic Word Repetition Test, Prose Memory, Corsi's Block-Tapping Test, Digit cancellation test, CPM, Verbal fluency (phonemic and semantic), Denomination, Constructional apraxia, Ideomotor apraxia (right and left limb), IADL, NPI, GDS	Reporting: 4 External validity: 0 Bias: 4 Confounding: 0 Total: 8
			IG (Specific treatment with TNP), n=7: TNP software on a touch-screen computer to stimulate cognitive function Assisted by a neuropsychologist	Fenney & Lee 2010		
			CG (Aspecific treatment), n=4: Cognitive activities supposed to balance the TNP intervention and a semi-structured interview on relevant events of life. Assisted by a neuropsychologist	60 mins, 3x/week, 4 weeks		
Lee et al. 2013	RCT	Diagnosed AD (International Classification of Diseases 10th Revision or Diagnostic and Statistical Manual of Mental Disorders, 4th Edition) Early dementia (score of 1 on screening with CDR) 60 years and older	n=24 (♂ 6, ♀ 13) ø age = 77.7 (±6.07) **IG 1 (CELP)**, n=7: CELP using a touch-screen notebook computer Serious games: face-name recognition, grocery shopping while cooking, taking the bus, categorization and counting of objects Training of attention, working memory and focus on one memory training theme		MMSE, DRS, HKLLT, BAPM, MBI, HKLIADL, GDS Qualitative feedback	Reporting: 9 External validity: 0 Bias: 5 Confounding: 3 Total: 17
			IG 2 (TELP), n=6: TELP identical to CELP in content and structure			
			CG, n=6: General cognitively challenging activities, e.g. card sorting			
McEwen et al. 2014	Single Case Study	Vascular dementia Cognitive impairment	n=1 (♂) age = 78 Score of 12 at the Montreal Cognitive Assessment Daily medication Left visual field deficit Full ROM + strength Virtual reality training program (interactive rehabilitation exercise IREX software) Progressive training (specific games for balance and functioning) Session split into 25mins of exercise time and 35mins of resting and explaining how to play upcoming game Sessions were held at the participant's home	60 mins, 5x/week, 2 weeks	Interviews with the caregiver, documentation of training events	

Table 2. Continued

Author, year	Study design	Subjects	Intervention: Type	Intervention: Extent	Instruments	Study quality
Padala et al. 2012	RCT	History of mild AD dementia along with MMSE score ≥18 (upper limit 29) 60 years and older Residing in assisted living facility	**IG (Wii-Fit),** n=11 (♂3, ♀ 8) ø age = 79.3 (±9.8) Wii-Fit program including strength training, yoga and balance games	30 mins, 5x/week, 8 weeks	MMSE, BBS, TT, TUG, BADL, IADL, QOL-AD	Reporting: 10 External validity: 0 Bias: 5 Confounding: 4 Total: 19
			CG (Walking), n=11 (♂ 3, ♀ 8) ø age = 81.6 (±5.2) Walking indoors	30 mins, 5x/week, 8 weeks		
Schreiber 1999	RCT	Alzheimer's disease dementia or vascular dementia according to the criteria of the DSM-IIIR (Diagnostic and Statistical Manual of Mental Disorders)	IG (Virtual training), n=7: (♂ 2, ♀ 5) ø age = 80.86 (±4.60) Virtual apartment: Participants either had to find a certain room in the apartment or certain targets in a room	30 mins, 5x/week, 10 sessions	MMSE, RBMT (Route learning immediate and delayed, Picture test), NAI (Figure test, Picture test)	Reporting: 8 External validity: 0 Bias: 6 Confounding: 1 Total: 15
			CG (Social stimulation), n=7 (♂ 1, ♀ 6) ø age = 78.86 (±6.72) Chat with psychologist to keep social stimulation	30 mins, 5x/week, 10 sessions		
Talassi et al. 2007	NRS	Clinical diagnosis of MCI or MD according to NINCDS-ADRA	**MCI IG (Cognitive rehab program)**, n=30 (♂ 13, ♀ 17) ø age = 76.2 (±7.3) **1. CCT**: The TNP software was used to stimulate cognitive function **2. OT**: Exercises that reproduce basic ADL **3. BT**: Conversations and behavior therapies to treat mood symptoms	30-40 mins for each activity, 4x/week, 3 weeks	MMSE, DS (forward and backward), Verbal fluency (phonemic and semantic), Visual search, RBMT Episodic memory (immediate and recall), Figure Rey (copy and recall), Digit Symbol Test, Clock Drawing, PPT, BADL, IADL, GDS, Stai (Y1 and Y2), NPI	Reporting: 7 External validity: 0 Bias: 5 Confounding: 3 Total: 15
			MD IG (Cognitive rehab program), n=24 (♂ 6, ♀ 18) ø age = 75.9 (±10.4) **1. CCT** **2. OT** **3. BT**	30-40 mins for each activity, 4x/week, 3 weeks		
			MCI CG, n=7 (♂ 4, ♀ 3) ø age = 76.1 (±7.0) **1. PR**: Treatment on the basis of possible presence of concomitant physical pathology **2. OT** **3. BT**	30-40 mins for each activity, 4x/week, 3 weeks		
			MD CG, n=5 (♂ 0, ♀ 5) ø age = 81.0 (±4.7) **1. PR** **2. OT** **3. BT**			

Table 2. Continued

Author, year	Study design	Subjects	Intervention		Instruments	Study quality
		IC	Type	Extent		
Tárraga et al. 2006	Case Control Study	Diagnosis of presumed AD MMSE score between 18 and 24 65 years and older GDS score of 3 or 4 At least 1 year of ChEIs treatment before inclusion into the study Attention at a daycare center in Barcelona for 5 days/week	**IG (IMIS)**, n=18 (♂ 5, ♀ 13): ø age = 75.8 (±5.9) **1. IMIS:** Treatment with an interactive multimedia internet-based system (Smartbrain) **2. IPP:** Cognitive stimulation tasks, workshops (e.g. music therapy, physical activity, art and crafts) and reinforcement of IADL **3. ChEIs treatment**	IMIS sessions between 15 and 25 mins IPP: 3,5h 3x/week, 24 weeks	MMSE, ADAS-Cog, SKT, BNT, Verbal fluency (phonemic and semantic), RBMT Story recall, RDRS-2, GDS	Reporting: 7 External validity: 0 Bias: 4 Confounding: 2 Total: 13
			IG (IPP), n=16 (♂ 2, ♀ 14) ø age = 77.4 (±4.7) **1. IPP** **2. ChEIs treatment**	IPP: 3,5h 3x/week, 24 weeks		
			CG (ChEIs), n=12 (♂ 0, ♀ 12) ø age = 76.9 (±4.5) **1. ChEIs treatment**	24 weeks		

Abbreviatons: AchE-I = Acetylcholinesterase inhibitor; AD = Alzheimer's disease; ADAS-Cog = Alzheimer's Disease Assessment Scale-Cognitive; BADL = Katz's Basic Activities of Daily Living; BAPM = Brief Assessment of Prospective Memory-Short Form; BBS = Berg Balance Scale; BNT = Boston Naming Test; BT = Behavioral therapy; CCT = Computerized cognitive training; CDR = Chinese Clinical Dementia Rating Scale; CELP = Computer-assisted errorless learning program; CG = Control Group; ChEIs = Cholinesterase inhibitors; CPM = Raven's Coloured Progressive Matrices; DRS = Mattis Dementia Rating Scale; DS forward/backward = Digit Span forward/backward; GDS = Geriatric Depression Scale; HKIADL = Hong Kong Lawton Instrumental Activities of Daily Living Scale; HKLLT = Hong Kong List Learning Test; IADL = Lawton & Brody's Instrumental Activities of Daily Living; IC = Inclusion criteria; IG = Intervention Group; IMIS = Interactive multimedia internet-based system; IPP = Integrated psychostimulation program; IREX = Interactive Rehabilitation Exercise; MBI = Chinese Version of the Modified Barthel Index; MCI = Mild cognitive impairment; MD = Mild dementia; Mins = Minutes; MMSE = Mini Mental State Examination; MODA = Milan Overall Dementia Assessment; N = Number; NAI = Nürnberger Alters Inventar; NINCDS-ADRDA = National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association; Nintendo DS = Nintendo Double Screen; NPI = Neuropsychiatric inventory; NRS = Non-randomized controlled trial; OT = Occupational therapy; PA = Physical activity; PPT = Physical Performance Test; PR = Physical rehabilitation; QoL-AD = Quality of Life-AD; RBMT = Rivermead Behavioral Memory Test; RCT = Randomized controlled trial; RDRS-2 = Rapid Disability Rating Scale-2; ROM = Range of motion; SKT = Syndrom Kurztest; Stai-Y1/-Y2 = State-trait Anxiety Inventory Y1/-Y2; TC = Tech Club; TELP = Therapist-led errorless learning program; TNP = Terrain Navigator Pro; TT = Tinetti Test; TUG = Timed Up And Go; TV = Television; VR = Virtual reality.

Table 3. Results feasibility analysis

Author, year	Results			
	Comprehensibility/playability	**Adherence/commitment**	**Acceptance/enjoyment**	**Risks/safety issues**
Benveniste et al. 2010	Caregiver assisted during the group sessions Even on lowest difficulty level where patients did not have to click on right keys but only had to hover over highlighted notes, they felt empowered Guidance of the caregiver was needed with using the remote control In challenge mode, failure is rather likely due to small size of the keys on screen → lots of time and help required → patients had trouble following simple rhythms and were unable to recognize songs In improvisation mode, patients felt overwhelmed creating their own song		Social interaction was encouraged Participants experienced great fun when playing together with other patients or their family	
Colombo et al. 2012	Caregiver supervised the session Games were comprehensible so that difficulty levels between 3 (moderate difficulty) to 7 (highest difficulty) could be reached	Total time played ranged from 40 to 240mins	Good level of involvement by the ones that looked interested in the game and technology Subjects appreciated games	Games perceived to be beneficial for health and mobility No adverse events
Cutler et al. 2015	Session led by two facilitators Use of technology should be tailored to participants' interests to create curiosity and acceptability Initial support required to get familiar with technology; over time participants were able to successfully engage independently in activities Slower paced games with fewer moving graphics were easier to engage with	Participants actively engaged with technology for extended periods of time	Learning to use new technology was the most enjoyable aspect of the sessions Participants felt highly motivated to learn new skills Using their mental abilities to engage with technology was perceived as appealing Digital PA games were found to be enjoyable Challenging perceptions of participants' own abilities created sense of empowerment Creating avatars was fun and helped participants to bond Access to different technologies during each session promoted both pursuing own interests and being part of the group Gaming devices as catalysts for social interaction → initiation of conversation about technology and games or previous life experiences and current hobbies	

Table 3. Continued

Author, year	Results: Comprehensibility/playability	Adherence/commitment	Acceptance/enjoyment	Risks/safety issues
Fenney & Lee 2010	Experimenter assisted the sessions All participants could improve game performance over time After a couple of weeks, participants were able to play the game without instructions from the experimenter 2 participants were able recognize their own avatar 1 participant explained the rules of the game, described how to use controller and how to bowl	Attendance ranged between 5 and 8 sessions Participants showed up prepared and motivated	Communication and interaction (e.g. providing help) among the players was encouraged by the game	
Galante et al. 2007		1 dropout in CG (poor compliance)		
Lee et al. 2013	IG 1 and IG 2 assisted by occupational therapist No info on supervision for CG Participants found learning to use computer was not difficult	5 dropouts in total (deterioration in medical condition)	Participants liked and enjoyed the memory training program and found them to be helpful for their daily life	
McEwen et al. 2014	Monitored by a kinesiologist Participant was able to understand information provided about the VR, the equipment and his role as player Participant could not remember earlier sessions due to memory and concentration deficits → often distracted while playing Daily instructions were required, no progression of task complexity possible Participant was frequently unable to attend left-sided activities because of his visual field deficit Participant was able to complete entire game set in each session with sufficient rests between the applications	Participant attended all sessions and was always cooperative		Participant was wearing physiotherapy belt to ensure safety No adverse events
Padala et al. 2012	Assisted by research personnel One technical difficulty was encountered	CG had greater exercise compliance than IG Switching between exercises on Wii-Fit was time consuming ø exercise time: 22 mins		
Schreiber 1999	IG assisted by a therapist CG intervention held by a psychologist			
Tárraga et al. 2006		3 dropouts in IMIS IG (rapid disease progression) All other patients completed minimum requirement of 58 sessions		

Abbreviations: CG = Control group; IG = Intervention group; IMIS = Interactive multimedia internet-based system; VR = Virtual reality.

Study Interventions
Five studies focused on serious games targeting physical activity[26–30]. Among those studies was only one with an RCT design[28]. Five studies focused on serious games targeting computer-assisted cognitive training[23–25,31,32]. One of them complemented the computer-assisted cognitive training with occupational therapy and behavioral training[24], whereas another study additionally integrated additional cognitive stimulation tasks, music and physical activity workshops, and Cholinesterase inhibitors (ChEIs) treatment[25]. One study had a video game-based music therapy with only low movement requirements as intervention program[22].

The intervention sessions took between 20 minutes and almost 4 hours per session[25]. One study did not provide information on duration22. Frequency varied between once[22,29] and 5 times per week[28,30,32]. One study did not provide concrete information on frequency[27]. Total intervention period differed between 2 weeks30 and 24 weeks[25]. Again, one study did not provide information on intervention period[26].

In 3 studies, participants played the serious games in groups[22,27,29]. In 4 studies, participants played the serious games on an individual basis[23,30–32], whereas one of them was a single-case study[30]. The IG participants of one study played the games individually; the comparative intervention was performed in groups[28]. Three studies did not clearly state whether the intervention was applied in a group or single setting[24–26]. Nine studies altered the intensity of intervention (e.g. alteration of difficulty levels or permission of breaks when subjects felt fatigued) according to the individual performance of the players[22,23,25–30,32]. Two studies did not provide any information on intervention intensity[24,31]. However, only 2 studies reported that the serious game was explicitly developed for people with dementia[22,23]. All other studies used serious games that had already been on the market (e.g. Nintendo Wii Bowling) and selected games that met the need of the study population[24,25–31,33].

Feasibility and Effectiveness
Information on feasibility aspects could be drawn out of 10 studies[22,23,25–32]. Feasibility results are shown in *Table 3*. Information on effectiveness could be drawn out of 6 studies with a controlled design[23–25,28,31,32]. The evaluation of the methodological quality of the 6 controlled studies is reported in *Table 4*, and the effectiveness results are shown in *Table 5*.

Table 4. Median methodological scores of effectiveness studies

Median methodological scores	
Reporting (max. 11)	7.5
External validity (max. 3)	0
Internal validity/bias (max. 7)	5
Internal validity/confounding (max. 6)	2.5

Feasibility Findings
(i) Comprehensibility/playability: Eight studies conducted the interventions under supervision[22,26–32]. In one study, participants of the intervention groups (IG) were supervised but no information were given to the control group (CG)[23]. Two studies did not provide any information on supervision[24,25]. Four of the studies explicitly reported that subjects needed guidance and support to understand and get along with the games[22,27,29,30]. However, 2 studies found that over time participants were able to engage independently with the serious games[27,29]. One study reported that the participants did not have difficulties in learning how to use the computer[23]. Another study mentioned that one technical difficulty was encountered[28]. The single-case study mentioned that although the subject was able to understand his role as a player and information was given on the game and equipment, daily instructions were still required and a progression of task complexity was not possible[30]. Regarding physical feasibility, the subject in the single-case study had difficulties to perform left-sided activities due to visual field deficits[30] and another study reported that slower paced physical activity games were easier to engage with[27]. Two studies found that slower and fewer moving graphics and bigger keys on the screen would be easier to handle for the subjects[22,27].

(ii) Adherence/commitment: In 4 studies, participants attended the sessions regularly or even played for extended periods of time and showed great commitment towards the serious games[26,27,29,30]. One study reported that all participants completed the required minimum of intervention sessions[25]. One study found that the CG had a greater exercise compliance than the IG and that switching between exercises on the Wii-Fit was time consuming which resulted in an average playing time of 22 out of 30 minutes[28]. Three studies reported dropouts[23,25,31]. One study reported 5 dropouts even before the assignment to the different study groups because of deterioration in the participants' medical condition[23]. In one study, one person dropped out of the CG because of poor compliance to the program[31]. In the other study, 3 participants dropped out of the IG because of rapid disease progression and institutionalization[25]. No dropout characteristics were reported.

(iii) Acceptance/enjoyment: Five studies found that subjects enjoyed and appreciated the games[22,23,26,27,29]. Participants of one study even

Table 5. Results effectiveness analysis

Author, year	Results		
	Cognitive function	**Physical function**	**Personal/behavioral aspects**
Galante et al. 2007	Stable MMSE scores found in IG Significant decline in MMSE scores found in CG at 9 months follow-up compared to baseline (p=0.04) and to 3 months follow-up (p=0.008)	No significant changes in physical performance	No changes found
Lee et al. 2013	Improvements in cognition for CELP and TELP - not significant for TELP (p>0.059 Greater cognitive improvements for CELP remarkable (p<0.05)	Greater improvements in functional measures for TELP remarkable (p=0.04)	Greater improvements for TELP remarkable in GDS (p=0.04)
Padala et al. 2012	No significant group-by-time interactions for cognition (p=0.7)	Improvements in balance and gait over time for IG and CG (p=0.0001) No significant group-by-time interactions for function (p=0.11)	No significant group-by-time interactions for QoL measures (p=0.61)
Schreiber 1999	Positive effect on specific domains of memory that were intended to be trained by the intervention Results are promising in that an interactive computer-based training with emphasis on person-environment interactions can be successfully used for the cognitive training of early-onset demented patients		
Talassi et al. 2007	Improvements in cognitive status (MMSE) of MD IG detectable (p=0.002) No significant cognitive effects (MMSE) found in MD CG Significant effects (semantic verbal fluency) found in MD CG (p=0043)	No significant changes in physical performance	Improvements in affective status of MD IG detectable in GDS (p=0.030), Stai-Y1 (p=0.011) and Stai-Y2 (p=0.044)
Tárraga et al. 2006	Improvements in cognition (ADAS-Cog; MMSE) for IMIS and IPP group compared with the ChEIs group (p<0.05) Longer positive effect for cognition found in IMIS group compared with IPP group Cognitive functions declined in ChEIs group	No significant changes found	No changes found

Abbreviations: ADAS-Cog = Alzheimer's Disease Assessment Scale-Cognitive; CELP = Computer-assisted errorless learning program ; CG = Control group; ChEIs = Cholinesterase inhibitors; IG = Intervention group; GDS = Geriatric Depression Scale; IMIS = Interactive multimedia internet-based system; IPP = Integrated psychostimulation program; MCI = Mild cognitive impairment; MD = Mild dementia; MMSE = Mini Mental State Examination; Stai-Y1/-Y2 = State-trait Anxiety Inventory Y1/-Y2; TELP = Therapist-led errorless learning program; QoL = Quality of Life.

reported that they had the feeling that playing the memory training program would help them in their daily life[23]. Three studies reported that participants especially enjoyed playing in groups where communication and social interaction were encouraged[22,27,29]. One study emphasized that subjects got highly motivated and developed a desire for continued learning using the technology and challenging their mental abilities[27].

(iv) Risks/safety issues: Three studies reported that no adverse events such as dizziness, loss of balance or falls occurred[26,28,30]. Other studies did not explicitly mention whether any adverse events occurred[22–25,27,29,31,32].

Effectiveness Findings
Table 4 presents the median methodological scores of the 6 controlled intervention studies. The median score of the studies on the checklist was 15 (range 8 - 19)[21]. The 2 highest scores were 19 and 17 points, respectively[23,28]. Two studies reached 15 points and one study had a total score of 13[24,32,25]. The lowest quality score was 8 points[31].

Table 5 presents the effectiveness findings in the domains of cognitive function, physical function and personal/behavioral aspects of the 6 controlled intervention studies.

(i) Cognitive function: The one study among the controlled studies which focused on physical activity could not identify significant group-by-time interactions (intention-to-treat-analyses assessed with RM-ANOVA) for cognition ($p=0.7$) (attention, calculation, language, orientation, visuoconstructional functions and word recall) in either the Wii-Fit group or the walking CG[28].
Two studies found significant improvements in cognition in their IG receiving computer-assisted cognitive training and in the groups that were treated with non-technical cognitive programs[23,25]. Improved cognitive areas were attention, calculation, construction, conceptualization, initiation/preservation, language, (prospective) memory, orientation, verbal learning, visuoconstructional and ideational praxis and word recall. However, improvements were greater in the computer-assisted IGs.
Two studies could identify positive effects in cognition only in their computer-assisted IGs compared with the non-computer-assisted CGs[24,32]. Improved areas were an immediate recall of meaningful visual information and retention of topographical information[32] and attention, calculation, language, orientation, visuoconstructional functions and word recall in mild dementia (MD) IG[24].
One study could identify stable MMSE scores in their IG that received a specific cognitive computer training[31]. Two studies found a significant decline in cognition in their CGs, of which one comprised a simple ChEIs treatment[25] and the other an aspecific cognitive training program[31]. The decline was apparent in the areas of attention, calculation, language, memory, orientation, visuoconstructional and ideational praxis and word recall.

(ii) Physical function: The one study among the controlled studies which focused on physical activity found improvements in balance and gait in both the Wii-fit IG and the walking CG, but no changes for basic and instrumental activities of daily living[28].
One study showed greater improvements in daily functions of the IG that received the errorless-learning intervention which was therapist-led as compared with the group that received the errorless-learning intervention which was computer-assisted[23]. Three of the computer-assisted intervention studies could not find significant functional changes in each of their study groups[24,25,31].

(iii) Personal/behavioral aspects: The one study among the controlled studies which focused on physical activity was not able to show significant changes regarding QoL in both the Wii-Fit IG and the walking CG[28].
One study found significant improvements in the affective status of the MD IG that received the computer-assisted cognitive intervention, whereas no changes were found for the MD CG[24].
One study showed greater positive changes in the affective status of the IG that received the therapist-led intervention as compared with the IG that received computer-assisted intervention[23].
No changes in personal/behavioral measures in either the IGs or the CGs were detected in 2 of the computer-assisted cognitive training studies[25,31].

Discussion

This systematic review examined the feasibility and effectiveness of serious games on cognition, physical function and personal/behavioral aspects in people with dementia.

The literature search revealed 11 relevant studies, among which were 10 studies[22,23,25–31] that covered feasibility aspects and 6 controlled studies[23–25,28,31,32] that examined effectiveness. Hereby, it has to be taken into consideration that in this systematic review only one controlled study was included which had a physical activity intervention[28], whereas the other 5 controlled studies all had cognitive interventions[23,25,31,32].

Feasibility criteria were defined and operationalized matching the context of this systematic review. A qualitative analysis approach according to Mayring[19,20] helped to analyze feasibility based on comprehensibility, adherence, acceptance, and safety issues. To our knowledge, the present paper is the first to make a systematic inventory and analysis of feasibility as well as effectiveness findings regarding serious games and dementia, and thus it adds to existing reviews on serious games and dementia[15,16] and papers that examined game design[15,34].

Feasibility analysis has shown that 9 out of 11 studies applied supervised interventions[22,23,26–32]. Although serious games were introduced as a low-cost alternative to traditional therapy interventions that can easily be installed and used at the user's home[12], this does not fully hold true. Hardware and software might be relatively cheap, but the costs for human resources (e.g. professional caregivers who assist the person with dementia when playing the serious games) must not be underestimated. Supervision is definitely required since an independent handling of the technique does not seem to work with people with dementia.

Three studies reported that serious games were played in groups in order to support understanding and handling of the technology[22,27,29]. Furthermore, playing in groups was found to be beneficial for social behavior of people with dementia. Studies reported that social interaction was fostered and participants experienced fun and enjoyed the challenge among the group. These findings counteract the purpose of serious games that they are meant to be played independently[12]. As people with dementia obviously enjoy playing serious games together in groups, further game development could emphasize the fun of joint gaming. Overall, serious games were found to be safe as no adverse events were reported[26,28,30]. However, reported dropout rates[23,25] due to disease progression, raises the question until which stage of dementia serious games are really feasible for affected people.

Out of 11 studies, 6 controlled studies could be used for analyzing effectiveness in different domains[23–25,28,31,32]. Four out of 6 studies found improvements in cognitive function in the groups that received serious game interventions[23–25,32], and one study could at least identify stable MMSE scores in the IG compared to the CG that showed a decline in MMSE scores[31]. These studies stimulated cognitive function with exercises e.g. for memory, language, calculating, perception, attention, orientation, and recognition. The games included tasks like grocery shopping; memorizing a shopping list or different foods; denominating, counting or finding objects; and taking the bus and were either played on a touch-screen notebook[23,31] or on a computer[24,25,32]. The one study that did not find any effects on cognitive function had, in contrast to all other controlled studies, a physical activity serious game intervention which incorporated yoga, balance and strength exercises on the Nintendo Wii Fit which is played in a free place in front of a TV[28]. Given these study results, it seems that serious games have the potential to at least maintain cognitive function at the same level over a certain period of time especially when serious games target cognition.

Studies, which had group interventions and found that social interaction was fostered by serious games, used music games, creating own avatars, cooking, bowling and other balance games. Games were played on the Nintendo Wii connected to a big screen, Nintendo DS or on a touch-screen-notebook such as an Apple iPad[22,27,29].

One study reported very long therapy hours with almost 4 hours per session (combination of max[25]. 25 minutes of the interactive multimedia-based session and 3,5 hours of workshops including physical activity, cognitive tasks, and crafting) which were split between the morning and the afternoon. The need for prolonged training hours can be questioned as this did not result in greater improvements compared with the 30 minutes-programs of other effectiveness studies[23,24,28,32].

However, greater improvements in daily functions and the affective status of people with dementia were found in an IG that received a therapist-led errorless learning program compared with an IG that received a computer-assisted errorless learning program[23]. At the same time, this study and another identified greater improvements in cognitive function in the computer-assisted IG compared with the therapist-led IG[23,25].

Nonetheless, the present findings do not allow to conclude that serious games for people with dementia have any additional effects compared to traditional interventions since 3 studies found improvements in both their IGs and CGs[23,25,28].

This systematic review and its outcomes obviously have some limitations. Regarding the search strategy, keywords could have been chosen more precisely and in combination with personal contact with dementia experts, this could have resulted in a more effective search with fewer off topic articles. However, we have no reason to think that our broad search strategy missed relevant studies. With its broad search strategy and in-exclusion criteria, this review attempted to include a large number of relevant studies for analyzing feasibility and effectiveness. Nevertheless, only a limited number of studies could be included, and the included studies represented a large variety of outcome domains and assessments. Given the large heterogeneity and low methodological quality of the few available studies, there presently is no basis for generalizing the outcomes of studies of serious gaming in dementia in the domains of cognitive and physical function and personal/behavioral aspects. None of the included controlled studies could score at least one point in the domain of external validity. The studies showed major deficiencies in methodological quality, particularly in providing information on the representativeness of study participants, the reporting of characteristics of patients lost to follow-up and in the reporting of adverse events, as well as in blinding subjects and research personnel and in randomizing subjects to the different IGs or the concealment of randomization.

Given the findings of this review, there is not sufficient scientific evidence to state whether serious gaming in people with dementia is effective or not. However, results of the available studies do suggest that serious gaming in dementia is feasible and an analysis of findings yielded insights, that can be taken into account in future studies into serious gaming in people with dementia. Although concrete recommendations for content and intervention duration, frequency and total intervention period could not be derived, the results of this systematic review and existing literature[12,34], lead to following recommendations for the design and implementation of serious games in people with dementia:
(i) Interventions should be supervised to support people with dementia when playing serious games to help them understand the instructions and the technology of the games[12,22,26,27,29,30].

(ii) Serious games should be well adapted to the target population and their individual impairments, capacities, and interests[12]. Individualization (e.g. auditory cues when a player has visual impairments, choosing preferred games from a pool of different games or creating own avatar) fosters motivation[12]. Thereby, the overall design should be kept simple; fewer moving objects, slow paces and big buttons seem to be more manageable for the target group of people living with dementia as found in 2 of the included studies[22,27,34] and that may help to prevent gaming frustration and reduce the need for intensive supervision.

(iii) Interventions should be played in groups (e.g. at home with family and friends or in nursing homes with other residents) in order to guarantee enjoyment and commitment to the games and to foster social behavior and interaction[22,27,29]. For a valuable orientation towards the future of serious games for people with dementia, the games should be implemented in the way that the joint gaming is the centerpiece of this technology.

(iv) Study quality should be improved by high methodological standards including robust RCTs, clearly defined samples, gold standard instruments, precise documentation of training intensity, implementation and participation, and CG design.

Further research in the field of serious games and dementia is recommended. The first step should be to gain greater experience in the feasibility of serious games in people with dementia. Therefore, standardized study designs with systematic, valid and reliable observational instruments for a better quantification of feasibility criteria (e.g. acceptance) are required. The in-depth investigation of the feasibility is the prerequisite for the scientific basis on which further effectiveness studies can be built as a second step in the research chain. Both feasibility studies and effectiveness studies are needed in order to obtain a larger pool of solid data for a better comparison of methods and results to get a clearer picture of feasibility and effectiveness of serious gaming in people with dementia.

As indicated by the findings of this review, further research in this field is needed, but also worth the effort. Reviews of studies of serious gaming in older adults without dementia also identified methodological shortcomings, but overall also these reviews highlighted the large potential of serious gaming for improving functioning in older adults[35,36]. An effective utilization of the strengths of serious games, such as motivation and positive mood through joint gaming, adaptation to the player's needs, real-time feedback delivery, the choice of playing whenever one feels like as the games can be installed at the user's home and the low installation costs are the key points that have the potential to lead to an added value of serious gaming in people with dementia[12].

Conclusion

This review shows that serious gaming in people with dementia is feasible and may be beneficial under certain conditions. However, there presently is not sufficient evidence to draw conclusions regarding the effectiveness of serious gaming in people with dementia. Further research needs to take into account feasibility aspects as well as methodological aspects to determine the effectiveness of serious games in people with dementia. Games should be well adapted to individual needs and people with dementia need to be familiarized with technology as well have assistance while playing. Supervision and playing in groups seem to be keys to success when implementing serious game interventions. Taking this into account, serious games may have the potential to be implemented as a rehabilitative means to target cognitive, physical and behavioral aspects.

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