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Computer-based cognitive interventions for people living with dementia: a systematic literature review and meta-analysis

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ABSTRACT

Objectives: To estimate the efficacy of computer-based cognitive interventions for improving cognition in people with dementia (PWD).

Method: Online literature databases were searched for relevant studies. Interventions were categorised as follows: cognitive recreation, cognitive rehabilitation, cognitive stimulation or cognitive training. A systematic review, quality assessment and meta-analyses were conducted.

Results: Twelve studies were identified. Their methodological quality was acceptable according to Downs & Black criteria, the weakest methodological area being the external validity. The meta-analyses indicated cognitive interventions lead to beneficial effects on cognition in PWD (SMD −0.69; 95% CI = −1.02 to −0.37; $P < 0.0001$; $I^2 = 29\%$), depression (SMD 0.47; 95% CI = 0.16 to 0.78; $p = 0.003$; $I^2 = 0\%$) and anxiety (SMD 0.55; 95% CI = 0.07 to 1.04; $P < 0.03$; $I^2 = 42\%$). They benefited significantly more from the computer-based cognitive interventions than from the non-computer-based interventions in cognition (SMD 0.48; 95% CI = 0.09 to 0.87; $P = 0.02$; $I^2 = 2\%$).

Conclusion: Computer-based cognitive interventions have moderate effects in cognition, and anxiety and small effects in depression in PWD. No significant effects were found on activities of daily living. They led to superior results compared to non-computer-based interventions in cognition. Further research is needed on cognitive recreation and cognitive stimulation. There is also a need for longer-term follow-up to examine the potential retention of treatment effects, and for the design of specific outcome measures.

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KEYWORDS
Cognitive rehabilitation; cognitive stimulation; dementia; Alzheimer disease; computer

Introduction

Computer use may reduce cognitive decline in older people and computer-based cognition focused applications have the potential to provide a useful and cost effective intervention for people with dementia (PWD). Recent epidemiological data support the hypothesis that computer-based leisure activity could be a protective factor against cognitive decline and dementia (Almeida et al., 2012; Xavier et al., 2014). An initial analysis of the data set of the English longitudinal study of aging (ELSA) indicated that the use of email/internet may reduce cognitive decline (Xavier et al., 2014). Thus, the regular use of computers and computer-based cognition focused interventions might help reduce the pace of cognitive decline. There is a pressing demand to improve psychosocial interventions with PWD and their carers, and the utilisation of innovative methods could help to meet this demand (Garcia-Betances, Jimenez-Mixco, Arredondo, & Cabrera-Umpierrez, 2014). Non pharmacological interventions have been shown as a realistic and affordable contribution to the provision of care for PWD (Olazarán et al., 2010).

Information and Communication Technologies (ICT) in general have been increasingly provided as a support for patients and their carers (Boots, de Vugt, van Knippenberg, Kempen, & Verhey, 2014; Franco-Martín, González Palau, Ruiz, Vargas, & Solis, 2011; Oriani et al., 2003), and computer-based programmes have been developed specifically to target dementia by aiding the rehabilitation of cognitive and everyday functions (Cipriani, Bianchetti, & Trabucchi, 2006). Computerised instruments have been reported to have advantages compared to paper and pencil batteries such as the standardisation of the administration and the stimulus presentation, the automated comparison with an individual's prior performance and efficiencies of staffing and cost (Wild, Howieson, Webbe, Seelye, & Kaye, 2008). On the other hand, the lack of familiarity of older adults with computers (Zygouris & Tsolaki, 2015) has been raised as an obstacle. These peculiarities justify a specific review of computer-based instruments. As a matter of fact, computer-based interventions are cited in many of the literature reviews on cognitive interventions (Bahar-Fuchs, Clare, & Woods, 2013; Clare, Woods, Moniz Cook, Orrell, & Spector, 2003; Kurz, Leucht, & Lautenschlager, 2011; Martin, Clare, Altgassen, Cameron, & Zehnder, 2011; Woods, Aguirre, Spector, & Orrell, 2012). However, there is no specific review of computer-based cognitive interventions in PWD, except for a review protocol on assistive technologies

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Authorship
JAGC and EC developed the original idea. JACG, AL and EC performed the search strategy, extracted data, and wrote the manuscript. MAFM, MVPB and MO contributed to the drafts of the paper and provided valuable comments during the process of writing this manuscript.

Table 1. Cognitive activities.

	Cognitive recreation	Cognitive rehabilitation	Cognitive stimulation	Cognitive training
Format	Individual or group	Individual	Group or dyad	Individual or group
Setting	Occupational use of Computers (e-mail, internet, games, reading, information)	Virtual or real world	Real world	Laboratory, clinic
Goals	Reduce the digital gap, use technology, leisure time enjoyment	Improve or maintain overall cognitive performance in relation to collaboratively set goals, build on the person's strengths, compensate for impairments	Improve or maintain overall cognitive performance, enhance social functioning, participation and enjoyment	Improve or maintain specific cognitive abilities
Focus	Leisure and recreation	Cognitive abilities, Activities of everyday life	Cognitive abilities, Activities of everyday life, social interactions	Specific cognitive abilities and processes (digit span, working memory, visual memory, etc.)
Stakeholders	Carer if necessary	Carer, therapist	Carer, therapist, group	Therapist

for memory support in dementia (Van der Roest Henriëtte, Wenborn, Dröes, & Orrell, 2012) and a review that focuses on assistive technologies and unmet needs, but not on treatments or interventions (Lauriks et al., 2007). Among the criticism that computer-based cognitive training (CT) has received, Owen et al. (2010) questioned whether the benefits of CT would actually transfer to other untrained tasks. They carried out a randomised control trial with over 11,000 healthy adults and found no transfer capacity, even though they did find improvement in the trained tasks (Owen et al., 2010). Thus, the issue of generalisability should be taken into account when analysing this type of interventions.

Even though there have been systematic reviews about computerised CT among healthy older adults (Kueider, Parisi, Gross, & Rebok, 2012; Lampit, Hallock, & Valenzuela, 2014), no specific reviews addressing the needs and characteristics of PWD have been carried out. The needs, characteristics and responses to treatments of PWD are specific and different from those of people without dementia and people with mild cognitive impairment (Gauthier et al., 2006; Milwain, 2000). Thus, it is necessary to study their specificity, carrying out analyses of studies that target exclusively PWD.

Classifying cognitive interventions

Terms such as cognitive stimulation (CS), CT and cognitive rehabilitation (CR) have been used inconsistently in the dementia literature. However, there is a need to differentiate those concepts and to agree on their proper use (Woods et al., 2012). CT is a guided set of standard tasks that replicate specific cognitive functions; each task having several difficulty levels tailored to the individual's ability and offered in individual or group sessions (Clare et al., 2003). CR is an individualised intervention to help people with their cognitive impairments, PWD and their carers work together with the healthcare professionals to identify relevant goals and define strategies for addressing them, improving performance in natural environments and everyday life (Bahar-Fuchs et al., 2013). Several literature reviews of CR treatments have been published (Li et al., 2011; Massoud et al., 2007; Simon, Yokomizo, & Bottino, 2012; Teixeira et al., 2012). Finally, CS is an intervention for PWD which offers a range of enjoyable activities providing general stimulation for thinking, concentration and memory usually in a social setting, such as a small group (Woods et al., 2012); it is aimed at general enhancement of cognitive and social functioning (Clare et al., 2003). An individualised form of CS (individualised Cognitive Stimulation Therapy; iCST) has been tested in which the treatment is delivered in a dyad formed by the carer and the person with dementia (Orrell, Woods, & Spector, 2012; Orrell, Yates, et al., 2012). We propose the additional category 'cognitive recreation' (CRC) as a non-specific cognitive activity involving the regular use of computer games, internet, e-mail, etc., for leisure purposes without a specific aim of improving functioning. Table 1 summarises the main characteristics of each of these concepts.

The aim of this systematic review is to evaluate the evidence for the potential cognitive benefits of computer-based activities for PWD.

Methods

Types of interventions

This review centred on computer-based interventions addressing cognition focused needs for PWD utilising personal computers, laptops, tablets or mobile phones, using a screen as an interface. This includes CT, CR and CS programmes as well as non-specific cognitive activity for leisure purposes. As computer-based interventions have aspects specific to them (e.g. a novel interface) and also specific advantages (e.g. tailoring of treatments, new stimulus on each session) there is a need to analyse them separately.

Participants

The target population were people living with different types of dementia including all levels of cognitive impairment. The diagnostic categories included were Alzheimer's disease, fronto-temporal dementia, vascular dementia and mixed Alzheimer's and vascular dementia.

Severity of dementia was indicated through group mean scores, range of scores, or individual scores on a standardised scale such as Global Dementia Rating Scale (GDS) (Reisberg, Ferris, de Leon, & Crook, 1982), Clinical Dementia Rating (CDR) (Berg et al., 1982), or Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975).

Search engines

Search engines used were The Cochrane Library, MEDLINE, EMBASE, PsycINFO, CINAHL ALOIS, the Specialised Register of the Cochrane Dementia and Cognitive Improvement Group (CDCIG), Scielo, Psicodocs, LILACS, web of science and PubMed. The cited literature in the matching articles was examined in order to search for other papers, which could have been missed in the review carried out through the search engines.

Search terms

The following search terms were used in combination: dementia, Alzheimer disease (AD), cognitive, memory, reality orientation, stimulation, training, rehabilitation, computer, technology and telerehabilitation. See Annex 1 for search terms combination cascade.

Inclusion criteria

(1) Before and after studies, randomised controlled trials (RCTs) and case control studies whose types of participants included people with dementia of any type and any age, living in community and care settings.
(2) Quantitative and mixed-method studies.
(3) Empirical studies in English and Spanish language published in peer reviewed journals between 2000 and 2014 (as previous studies might be based in outdated technologies which wouldn't be comparable with current available ICT).
(4) Studies clearly stating their aims, objectives and methods.
(5) Studies that used psychometrically robust outcome measures including cognition to collect primary outcome data.

Exclusion criteria

(1) Studies with people with mild cognitive impairment but not with a dementia diagnosis.
(2) Studies with mixed participants (with and without dementia, dementia and MCI, etc.) which did not differentiate the results of each group.
(3) Multimodal interventions not able to state which part of the intervention is responsible for the outcomes.
(4) Case studies.

Types of outcome measures

Outcomes were evaluated in terms of change from baseline to the end of treatment and, if available, to follow up. They were considered for inclusion only if they were assessed with standardised measures. Reports of performance based on behavioural observation or qualitative measures were considered as additional information. Rates of compliance, attrition and reasons for this were noted. The following areas were considered relevant: cognitive effects, non-cognitive effects (mood, quality of life, etc.) and generalisability (improvement in everyday life, instrumental activities of daily living, etc.).

Selection of studies

The search yielded 35,083 papers (6035 after the exclusion of duplicates). On the basis of the inclusion criteria, the titles, keywords and abstracts were assessed by the first author obtaining a total of 274 relevant papers out of this first stage of the selection process. Those 274 papers were then assessed by two authors on the basis of abstracts and full copies of the article when needed. Any disagreement about the inclusion of papers was discussed in a consensus meeting. Seven further studies were found through hand search, tracking cited references in other studies and relevant literature reviews. The selection process resulted in a total of 37 studies, which were screened on the base of full articles. At this stage, a third reviewer also assessed the studies. Authors of four articles were contacted for additional information. Finally, the three reviewers agreed that 12 studies met the inclusion criteria. Based on the criteria described in the introduction, reviewers decided by consensus which category best described the intervention carried out in each study (CRC, CR, CS or CT). Figure 1 presents a flowchart illustrating the selection process.

Data management

The selected studies were organised into clusters by intervention type, and a standardised data extraction form was used, as suggested by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins 2008), including specific categories that were considered essential for this review (e.g. type of technology used, generalisability). Selected studies were examined for their characteristics: focus of the intervention; sample size, age and education of participants; characteristics of the experimental and control groups and the interventions they received; compliance and dropouts; kind of technology used; cognitive, non-cognitive findings; and follow up.

A meta-analysis was carried out with those studies that provided the necessary data. The I^2 statistic was used to determine heterogeneity of the studies; if I^2 was $\leq$50%, the fixed-effect model was used and if I^2 was $>$50%, the random effect model was used (Borenstein, Hedges, Higgins, & Rothstein,

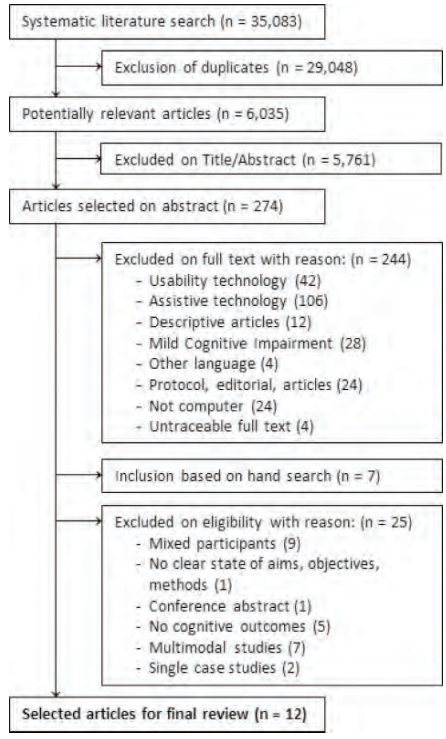

Figure 1. Flowchart of the search strategy.

2010). Subgroup analyses were conducted when heterogeneity was detected. The effect sizes were analysed using the Cochrane Review Manager software RevMan 5.3. By convention, an effect size of 0.2, 0.5 and 0.8 was considered small, moderate and large, respectively (Cohen, 1988).

Quality assessment

To assess the methodological quality of the included trials, we used Downs and Black's checklist (Downs & Black, 1998). The checklist assesses both randomised and non-randomised studies. One of its strengths is that it includes three items for external validity (generalisability), an issue which has been mentioned as important when speaking about cognitive interventions (Hopper et al., 2013; Kurz et al., 2011). The tool evaluates studies' quality in terms of reporting, external validity, bias, confounding variables and power, comprising a total of 27 items. The item 27 (power) was not used for this review, as it did not apply to most of these studies. The maximum score varied depending on the design, 26 for randomised control trials (RCT) and 23 for the other types of studies.

Two reviewers assessed the studies with the checklist. To ensure inter-rater reliability, both assessed an initial paper independently, and inter-rater agreement was then evaluated. They discussed the items on which they did not agree, reaching consensus in their criteria, and then assessed a second paper independently. The concordance index raised from moderate (Kappa = 0.46; $p = 0.019$) for the first paper to substantial for the second one (Kappa = 0.68; $p = 0.000$), according to Landis and Koch criteria (Landis & Koch, 1977).

The process characteristics of the interventions were also reviewed, as suggested in previous systematic reviews that included heterogeneous studies (Boots et al., 2014; Zijlstra et al., 2007). Thus, we checked whether the intervention studies provided information on the following: (1) clear description of the computer intervention (technology and software); (2) existence of a treatment protocol; (3) the performance of intervention according to its protocol; (4) the qualification of the facilitator; (5) effort to address generalisability of treatment results to everyday life; (6) reported dropouts; (7) reasons for dropouts; (8) intervention tailored to the needs of the patient; (9) whether treatment was individual or in groups; and (10) recommendations for improving or changing the intervention. Each item was scored '1' if the criterion was fulfilled, '0' if the criterion was not fulfilled, and '?' if the information was not provided or was unclear.

Results

Of the 12 articles included, two were about CRC, five about CR, two about CS, and three about CT. These studies are presented in Table 2. One study (Loewenstein, Acevedo, Czaja, & Duara, 2004) had a CR experimental intervention and a CRC control intervention, both computer-based, but the experimental intervention was multimodal. Seven studies were randomised control trials; two were case control studies; two were before and after studies and one was a mixed-methods study. As shown in Table 3, seven studies had active control groups drawn from different populations (e.g. people with mild cognitive impairment) receiving the same computer-based treatment as the intervention group. Of the studies comparing PWD to each other, three had active control groups receiving a paper and pencil intervention, and four receiving treatment as usual.

Participants

Sample sizes ranged from 5 to 348. The studies comprised a total sample of 700 participants, 376 of whom were PWD. 541 people participated in computer-based interventions, of which 269 were PWD. Table 2 shows a more detailed description of the participants.

In four of the 12 studies, the participants in the intervention group were receiving pharmacological treatment (Cipriani et al., 2006; Fernández-Calvo, Rodríguez-Pérez, Contador, Rubio-Santorum, & Ramos, 2011; Loewenstein et al., 2004; Tárraga et al., 2006); in two they did not receive treatment (Hofmann et al., 2003; Jelcic et al., 2014); and six did not report it (Lee, Yip, Yu, & Man, 2013; Savage, Piguet, & Hodges, 2014; Talassi et al., 2007; Yamaguchi, Maki, & Takahashi, 2011; Zaccarelli, Cirillo, Passuti, Annicchiarico, & Barban, 2013; Zhuang et al., 2013).

Dosage of the interventions

The interventions consisted of 10 to 72 working sessions ($M = 30.83$; $Sd = 21{,}62$), and the frequency of the sessions varied from 1 to 4 times per week ($M = 2.75$; $Sd = 0.97$). Ten interventions were unimodal (Cipriani et al., 2006; Fernández-Calvo et al., 2011; Hofmann et al., 2003; Jelcic et al., 2014; Lee et al., 2013; Loewenstein et al., 2004; Savage et al., 2014; Yamaguchi et al., 2011; Zaccarelli et al., 2013; Zhuang et al., 2013) and two were multimodal (Talassi et al., 2007; Tárraga et al., 2006).

The duration of each training session was between 29 and 210 minutes ($M = 63.70$; $Sd = 53.80$). The duration of the computer-based activity of the treatments ranged from 21 to 75 minutes ($M = 45.56$; $Sd = 18.89$). While most of the interventions had a fixed duration, some of them varied it as the participant got used to the technology (Tárraga et al., 2006) or depending on his/her concentration capacity (Cipriani et al., 2006; Talassi et al., 2007). The total duration of the treatment was between 6 and 252 hours ($M = 49.31$; $Sd = 75.13$; $Md = 22.00$), of which between 6 and 90 hours were computer-based ($M = 28.74$; $Sd = 24.36$; $Md = 24.00$). In two studies, it was not possible to estimate the duration of the treatment sessions from the information provided by the authors (Hofmann et al., 2003; Yamaguchi et al., 2011) and in one the duration of the computer-based intervention was not provided (Talassi et al., 2007).

Five of the studies had a follow up between two and three months after the treatment. In four of them, the effects of the treatment were maintained.

Study quality and risk of bias

The total score of the studies in Downs & Black's checklist ranged from 12/26 (46%) to 21/26 (81%). The average score was 16.50 ($Sd = 3.06$) equivalent to a 63% of the possible marks (Table 4).

Reporting

Overall, the 12 studies scored 79% of the nine items that assessed reporting. Hypotheses or objectives and expected outcomes were clearly stated in all the studies. Eleven of the 12 described the characteristics of the participants, the

Table 2. Characteristics, measures, and outcomes of computer-based interventions with people with dementia.

Author /year	Design	Technology	Group	*n* / type of population	Intervention	Type of outcome	Findings
Cognitive rehabilitation							
Cipriani et al. (2006)	CCS	Computer	Intervention group	10 AD	NPT software: Neuropsychological Training, exercises with acoustic or visual inputs	General cognition	Sign. improvement in MMSE ($p = 0.010$)
						Mood	No sign. reduction in STAI (p = not reported, Mdiff STAI-XI $= -4.90$, Mdiff STAI-X2 $= -4.30$) and GDS (p = not reported, Mdiff $= -1.9$)
			Active CG	10 MCI, 3 MSA	Same intervention	General cognition	No sign. improvement in MMSE (p = not reported, Mdiff $= 0.7$)
						Mood	No sign. reduction in STAI (p = not reported, Mdiff STAI-XI $= -3.4$, Mdiff STAI-X2 $= -6.5$) and GDS (p = not reported, Mdiff $= -1.5$)
Fernández-Calvo et al., 2011	RCT	Wii with TV	Intervention group	15 mild AD	Stimulation programme with Big Brain Academy	General cognition	Sign. difference for intervention group (Mdiff $= 0.13$) on ADAS-Cog compare to Active CG ($p < 0.017$; Mdiff $= 4.01$) and Passive CG ($p < 0.05$; Mdiff $= 9.88$)
						Mood	Sign. reduction in EDC (Spanish version of the Cornell Depression Scale; Mdiff $= -5.33$) for the intervention group compare to the Active CG ($p < 0.017$) and Passive CG ($p < 0.001$)
						Others	Sig. improvement for intervention group in the NPI-Q compare to Active CG on the NPI-Q ($p < 0.001$)
			Active CG	15 mild AD	Treatment as usual, paper and pencil, Holistic Psychostimulation programme	General cognition	Sign. difference for active CG on ADAS-Cog compare to Passive CG ($p < 0.001$)
						Mood	Mean change in EDC (Mdiff $= -0.4$)
			Passive CG	15 mild AD	Usual care, waiting list	General cognition	No sign. improvement in ADAS-Cog (p = not reported; Mdiff $= 9.88$)
						Mood	Mean change in EDC (Mdiff $= 4.26$)
Hofmann et al., 2003	CCS	Computer touch screen	Intervention group	9 AD	ICT programme that relates to ADL	General cognition	Sign. improvement in MMSE ($p < 0.008$) for all groups taken together; AD performed sign. worse in MMSE ($p < 0.001$)
						Mood	Not assessed
						Others	Sign. worse in all four training variables (latency, $p < 0.027$; repeat of instruction, $p < 0.020$; mistakes, $p < 0.07$; multiple-choice questions, $p < 0.020$) compare to both Active CG; all groups: trend towards an improved performance in 4 training variables, but only sign. improvement in 'mistakes' because of AD ($p < 0.044$)
			Active CG	9 depressive episode, 10 healthy people	Same intervention	General cognition	Not reported
						Mood	Not assessed
						Others	Better performance in all four training variables than AD, no sign. difference between Active CG depression and Active CG healthy
Jelcic et al., 2014	RCT	Computer (Skype, windows)	Intervention group	7 AD	Teleconference with a far away therapist; lexical tasks, interpretation of written words, sentences and stories	General cognition	Sign. improvement in MMSE ($p = 0.030$)
						Mood	Not assessed
						Others	Sign. improvement in verbal expression (Phonemic, $p = 0.040$; Semantic, $p = 0.030$) and attention (digit cancellation, $p = 0.010$)
			Active CG 1	10 AD	Same intervention but therapist is present	General cognition	Sign. improvement in MMSE ($p = 0.010$)
						Mood	Not assessed
						Others	Sign. improvement in verbal episodic memory (Story immediate recall, $p = 0.030$)
			Active CG 2	10 AD	Different intervention: unstructured cognitive treatment with therapist (e. g. reading newspaper)	General cognition	No sign. improvement in MMSE (p = not reported, Mdiff $= -0.7$)
						Mood	Not assessed
						Others	Sign. decline in the test mean score (p = not reported), no improvement in any tests
Talassi et al., 2007	CCS	Computer-based TNP	Intervention group	30 MCI, 24 MD	CR programme with 3 activities: 1. CCT with TNP software, stimulate each cognitive function by a specific group of exercises; 2. OT, basic activity of daily living; 3. BT, treated mood symptoms utilising conversations and behaviour therapies	General cognition	MD: sign. improvement in MMSE ($p = 0.002$); MCI: no sign. improvement in MMSE (p = not reported, Mdiff $= 0.4$)
						Mood	MD: sign. reduction in GDS ($p = 0.030$) and STAI (STAI-X1, $p = 0.011$; STAI-X2, $p = 0.044$); MCI: sign. reduction in GDS ($p = 0.012$) and STAI (STAI-X1, $p = 0.030$; STAI-X2, $p = 0.000$)
			Active CG	7 MCI, 5 MD	Same intervention but instead of computer programme they received physical rehabilitation	General cognition	MD: no sign. improvement in MMSE (p = not reported, Mdiff $= 0.6$); MCI: no sign. improvement in MMSE (p = not reported, Mdiff $= -0.3$)
						Mood	MD: no sign. reduction in GDS (p = not reported, Mdiff $= -5.7$) and STAI (STAI-X1, Mdiff $= -7.2$; STAI-X2, Mdiff $= -10.8$); MCI: no sign. reduction in GDS (p = not reported, Mdiff $= -0.5$) and STAI (STAI-X1, Mdiff $= -2.8$; STAI-X2, Mdiff $= -6.8$)

(*continued*)

Table 2. (*Continued*)

Author /year	Design	Technology	Group	*n* / type of population	Intervention	Type of outcome	Findings
Cognitive training							
Lee et al., 2013	RCT	Computer-tablet	Intervention group	6 AD	Computerised errorless learning-based memory training programme with daily life training content	General cognition	No sign. improvement in MMSE ($p = 0.090$) and DRS ($p = 0.040$); Time effect on DRS ($p = 0.040$), treatment effect within groups on MMSE ($p = 0.040$) and DRS ($p = 0.030$)
						Mood	No sign. reduction in GDS ($p = 0.500$)
						Others	No sign. improvement in HKLLT ($p = 0.120$), BAPM ($p = 0.150$), MBI ($p = 0.020$), HKLIADL ($p = 0.400$)
			Active CG	6 AD	Same intervention but with a therapist and no computer: therapist-led errorless learning programme, training manual containing coloured print images	General cognition	No sign. improvement in MMSE ($p = 0.460$) and DRS ($p = 0.030$); Time effect on DRS ($p = 0.030$), treatment effect within groups on MMSE ($p = 0.090$)
						Mood	No sign. reduction in GDS ($p = 0.060$)
						Others	No sign. improvement in HKLLT ($p = 0.110$), BAPM ($p = 0.100$), MBI ($p = 0.460$), HKLIADL ($p = 0.420$)
			Passive CG	7 AD	Usual care, waiting list	General cognition	No sign. improvement in MMSE ($p = 0.260$) and DRS ($p = 0.630$)
						Mood	No sign. reduction in GDS ($p = 0.400$)
						Others	No sign. improvement in HKLLT ($p = 0.080$), BAPM ($p = 0.620$), MBI ($p = 0.290$), HKLIADL ($p = 0.540$)
Savage et al., 2014	B/A	Computer	Intervention group	2 mild SD, 3 moderate SD	Online word training programme at home: repetitive practice of pairing photographs of target item with item label and online naming tests after each week	General cognition	Not assessed
						Mood	Not assessed
						Others	Word training effect (mild: 90% or more; moderate: 48% to 84%); when taken as a group sign. improvement for trained items over time ($p = 0.031$) but not for untrained ($p = 0.125$); no sign. improvement on the control list
Zhuang et al., 2013	RCT	Computer	Intervention group	12 MCI, 7 DE	Human-computer interaction-based comprehensive training including e.g. picture memorisation	General cognition	No sign. improvement in ACE-R ($p = 0.157$, Mdiff DE = 8, Mdiff MCI = 4)
						Mood	Not assessed
						Others	Visuospatial ability (patients with less brain atrophy GCA $\leq$ 15, $p = 0.043$)
			Passive CG	8 MCI, 6 DE	Usual care	General cognition	No sign. improvement in ACE-R ($p = 0.418$, Mdiff = -2.21)
						Mood	Not assessed
Cognitive recreation							
Loewenstein et al., 2004	RCT	Computer	Intervention group	19 AD	Mental Stimulation, interactive computer games involving memory, concentration and problem-solving skills; homework assisted by a family member	General cognition	Sign. improvement in MMSE (group x time, $p < 0.05$); sign. decline in MMSE-Orientation (at 3 months follow up, $p < 0.010$)
						Mood	No sign. reduction in CES-D for both groups (patients' report, $p = 0.149$; Informants' report, $p = 0.033$); Mean change in CES-D patients' report (Mdiff at 12 week = -4.37; Mdiff at 3 months follow-u $p = -2.95$)
						Others	Intervention group compare to active CG: higher on the three-trial FNAT recall (at 12 weeks, $p < 0.010$), lower commission errors on the CPT (at 12 weeks, $p < 0.050$); Both group: sign. improvements in memory (IQCODE patients, $p < 0.001$ at post-test)
			Active CG	25 AD	Different intervention: Cognitive Rehabilitation, face−name association tasks, object recall training, functional tasks, orientation to time and place, visuo-motor speed of processing, use of memory notebook; homework assisted by a family member	General cognition	Sign. improvement in MMSE-orientation (at 12 weeks, $p < 0.010$; at 3 months follow-up, $p < 0.050$)
						Mood	Mean change in CES-D patients' report (Mdiff at 12 week = -0.96; Mdiff at 3 months follow-u $p = -3.20$)
						Others	Improvement in FNAT (learning, $p < 0.001$ at post-test and follow-up; recall, $p < 0.001$ at post-test and follow-up), Making-Change-For-A-Purchase test ($p < 0.050$ at post-test and follow-up) and in CPT (reaction time, $p < 0.010$ at post-test and follow-up); CG informants reported of sign. improvement in memory (IQCODE informants, $p < 0.0001$)
Yamaguchi et al., 2011	B/A	TV, players wore equipment with sensors	Intervention group	1 PD dementia, 1 VaD, 7 AD	Video sports-games: 1. move their hands, 2. move their legs to music; Caregivers were taught in advance how to motive and maintain empathetic two-way communication with PWDs	General cognition	Sign. improvement in HDS-R (HDS-R, $p = 0.002$)
						Mood	No sign. improvement in MOSES ($p = 0.054$)
						Others	Sign. improvement in visual spatial memory (Kohs, $p = 0.020$)

(*continued*)

Table 2. (*Continued*)

Author /year	Design	Technology	Group	*n* / type of population	Intervention	Type of outcome	Findings
Cognitive stimulation							
Zaccarelli et al., 2013	RCT	Multi-touch tablet or PC	Intervention group	118 AD, 106 aMCI	SOCIABLE Programme ICT based model: social activation, cognitive training sessions with 25 games covering the main cognitive skills and a book-of life application	General cognition	Sign. improvement in MMSE (AD, $p = 0.004$; aMCI, $p = 0.002$); no sign. improvement in CDR ($p =$ not reported)
						Mood	No sign. reduction in GDS (AD, $p = 0.107$; aMCI, $p = 0.104$); sign. reduction in GDS when all group are taken together ($p = 0.004$)
						Others	AD: sign. improvement in verbal memory (RAVL-immediate, $p = 0.002$; RAVL-delayed, $p = 0.001$), executive functions (DS backward, $p = 0.014$) and IADL ($p = 0.123$); aMCI: sign. improvement in verbal short-term memory (DS forward, $p = 0.024$), verbal long-term memory (RAVL-delayed, $p = 0.012$) and executive functions (PVF, $p = 0.012$)
			Active CG	124 healthy	Same computer-based intervention	General cognition	No sign. improvement in MMSE ($p = 0.113$); No sign. improvement in CDR ($p =$ not reported)
						Mood	No sign. reduction in GDS ($p = 0.148$)
						Others	Sign. improvement in verbal long-term memory (RAVL-delayed, $p = 0.001$), praxis (ROCF, $p = 0.003$) and executive functions (PVF, $p = 0.008$)
Tárraga et al., 2006	RCT	Computer	Intervention group	15 AD	1. IMIS using Smartbrain, interactive multimedia with 19 exercises covering the main cognitive skills; 2. IPP, daily programme in the day-care centre including cognitive stimulation tasks, workshops and reinforcement of IADL; ChEI treatment	General cognition	Mean change in MMSE (Mdiff at 12 week = 1.93; Mdiff at 24 week = 1.47) and in ADAS-Cog (Mdiff at 12 week = −2.54; Mdiff at 24 week = −1.07); Between group: sign. difference on general cognition after 12 weeks (ADAS-Cog, $p = 0.002$; MMSE, $p < 0.001$) and after 24 weeks (ADAS-Cog, $p = 0.06$; MMSE, $p = 0.001$); Training more effective for intervention group and Active CG on ADAS-Cog ($p < 0.05$); sign. difference on MMSE for intervention group and Active CG compare to Passive CG ($p < 0.05$)
						Mood	Scores remain stable in GDS (Pre/post score = 4)
			Active CG	16 AD	Same intervention (IPP + ChEI) without IMIS	General cognition	Mean change in MMSE (Mdiff at 12 week = 0.50; Mdiff at 24 week = 0.13) and in ADAS-Cog (Mdiff at 12 week = −2.44; Mdiff at 24 week = 1.12)
						Mood	Scores remain stable in GDS (Pre/post score = 4)
			Passive CG	12 AD	Usual care including only ChEI treatment	General cognition	Mean change in MMSE (Mdiff at 12 week = −1.08; Mdiff at 24 week = −1.50) and in ADAS-Cog (Mdiff at 12 week = 1.08; Mdiff at 24 week = 1.83)
						Mood	Scores remain stable in GDS (pre/post score = 4)

Note: ACE-R: Addenbrooke's Cognitive Examination-Revised; ADAS-Cog: Alzheimer's Disease Assessment Scale-Cognitive; AD: Alzheimer's Disease; ADL: Activities of Daily Living; aMCI: amnestic Mild Cognitive Impairment; B/A: Before and After Study; BAPM: Brief Assessment of Prospective Memory-Short Form; BT: Behavioural Training; CCS: Case Control Study; CDR: Clinical Dementia Rating; CCT: Computerised Cognitive Training; CES-D: Center of Epidemiological Studies-Depression Scale; CG: Control Group; ChEI: Cholinesterase inhibitor; CPT: Continuous Performance Test; CR: Cognitive Rehabilitation; DE: Dementia; DRS: Dementia Rating Scale; DS: Digit Span; EDC: Cornell Depression Scale; FNAT: Face-Name Association Test; GCA: Global Cortical Atrophy; GDS: Geriatric Depression Scale-Short Form; HDS-R: Hasegawa's Dementia Scale-revised; HKLLT: Hong Kong List Learning Test; IADL: Instrumental Activities of Daily Living; ICT: Information and Communication Technology; IMIS: Interactive multimedia internet-based system; IPP: Integrated psychostimulation programme; IQCODE: Informant Questionnaire of the Cognitive Decline; MBI: Modified Barthel Index; MCI: Mild Cognitive Impairment; MD: Mild Dementia; MMSE: Mini-Mental State Examination; MOSES: Multidimensional Observation Scale for Elderly Subjects; MSA: Multiple System Atrophy; NPI-Q: Neuropsychiatric Inventory Questionnaire; OT: Occupational Therapy; PD: Parkinson's Disease; PVF: Phonological Verbal Fluency; PWD: Person with Dementia; RAVL: Rey Auditory Verbal Learning Test; RCT: Randomised Control Trial; ROCF: Rey-Osterrieth Complex Figure; SCS: Single Case Study; Sd: Standard Deviation; SD: Semantic Dementia; STAI-XI-X2: State and Trait Anxiety; VaD: Vascular Dementia.

Table 3. Study population and control groups.

	Computer based		Non-computer based	
	IG	Active CG Same int.	Active CG Different int.	Passive CG No treatment
Cognitive recreation				
Loewenstein et al.	✓	–	✓	–
Yamaguchi et al.	✓	–	–	–
Cognitive rehabilitation				
Cipriani et al.	✓	✓	–	–
Fernández-Calvo et al.	✓	–	✓	✓
Hofmann et al.	✓	✓	–	–
Jelcic et al.	✓	✓	✓	–
Talassi et al.	✓	✓	–	–
Cognitive stimulation				
Zaccarelli et al.	✓	✓	–	–
Tárraga et al.	✓	✓	–	✓
Cognitive training				
Lee et al.	✓	✓	–	✓
Savage et al.	✓	–	–	–
Zhuang et al.	✓	–	–	✓

Note: Computer based: Computer, wii or tablet; IG: intervention group; CG: control group; Int.: intervention.

Table 4. Methodological quality of included studies (Downs & Black's criteria).

Authors	Reporting (9)	External validity (4)	Internal validity-bias (7)	Confounding (6)	Total	%
Cipriani et al.	6	2	4	4	16	62
Fernández et al.	7	2	5	4	18	69
Hofmann et al.	9	2	4	4	19	73
Jelcic et al.	8	2	5	5	20	77
Lee et al.	9	1	6	5	21	81
Loewenstein et al.	7	1	5	2	15	58
Savage et al.	6	2	4	1	13	50
Talassi et al.	8	1	4	3	16	62
Tarraga et al.	7	1	6	3	17	65
Yamaguchi et al.	6	2	3	1	12	46
Zaccarelli et al.	4	1	4	3	12	46
Zhuang et al.	8	2	4	5	19	73
Total (max score)	Reporting (108)	External validity (48)	Internal validity-bias (84)	Confounding (72)	(312)	
Total score	85	19	54	40	198	
%	79	40	64	56	63	

Note: Max. score: maximum possible score of the 12 studies together.

interventions implemented and the main findings. Three studies did not report the number of participants lost to follow up or their characteristics. Nine of the studies described the distribution of the principal confounders in each group including stage of dementia, education, comorbidities, age and medication. Seven studies provided estimates of the random variability in the data for the main outcomes. Finally, nine studies did not report on adverse events, and three reported that they did not find any.

External validity

Studies scored 40% of the possible items. One of the studies failed to report the actual probability values for the main outcomes. In 8 out of 12 studies the staff, places and facilities were representative of the usual treatment provided by local health services. Although 11 out of 12 studies described how participants were selected, none of them assessed if those participating in the study were representative of the entire population from which they were recruited.

Internal validity (bias)

This was the second strongest domain of those assessed, as the studies scored a 64% of the possible items. 11 studies (92%) provided sufficient evidence that appropriate statistical tests were used for analysis. In all the studies that had a follow up the period between the intervention and the outcome was the same for both groups (case control studies). Only two studies reported compliance with treatment, but actual compliance data was not provided, thus making it difficult to assess whether the interventions were adjusted to protocol. As expected, participants were not blind in any of the studies, as this is hard to achieve in psychosocial interventions. On the other hand, six of the studies blinded those measuring the main outcomes of the intervention. Finally the 12 studies all used reliable outcome measures.

Internal validity (confounding)

In this domain, the studies scored 56% of the possible items. The 10 studies that had a control group or different intervention groups, recruited their participants from the same population (e.g. hospital, care home, day care centre), and eight of them did it during the same period of time. In seven of the studies, subjects were randomised to the intervention groups. Six of the studies did the adequate adjustment for confounding in the analysis from which the main findings were drawn, or based their conclusions in intention to treat. Proportion of losses to follow up, if present, was too small to affect the main findings (less than 10%).

Process

Table 5 presents the process characteristics of the interventions. The reported total number of fulfilled items ranged from three to seven out of ten. Of the 108 process items across the 12 trials, 70 (60%) were fulfilled.

All papers except for one included a thorough description of the technology used (software and hardware). Ten of the interventions were protocolled and six of them reported whether the intervention was delivered according to protocol. Four of the studies stated the qualification of the facilitator.

Seven of the studies reported an effort to address generalisability, either by assessing daily life activities, doing the pre post assessment with stimuli different from the ones used in the treatment, or including stimuli related to the reality of the participants. Two studies did not report dropout rates, and one study failed to report on the reasons for dropout.

Six of the interventions were tailored to the individual needs of the participants (50%) either by adapting the level of difficulty to a baseline assessment, or including stimuli familiar to the patient. Two of the interventions were not tailored to the needs of the patients (17%), and in four cases (33%) it was not possible to obtain that information from the article.

Five of the interventions were individual and two were in groups. In four cases it was not possible to know from the article, and in one study the authors stated that the treatment could be delivered in an individual or group format (Zaccarelli et al., 2013).

Finally, recommendations for improvement were made by six of the 12 studies, mentioning the need to assess generalisability, the importance of finding the correct dosage of the intervention, the need to develop specific outcome measures to assess these kind of interventions, and the importance of

Table 5. Process characteristics of the interventions.

Author	Intervention	Protocol	According to protocol	Facilitator qualification	Generalisability	Dropouts	Reason dropouts	Tailored	Ind/group	Recommendations	Total
Cipriani et al.	1	1	0	0	1	1	n.a.	1	1	0	6
Fernández et al.	1	1	1	1	0	0	n.a.	0	1	1	4
Hofmann et al.	1	1	0	0	1	1	0	0	?	1	4
Jelcic et al.	1	1	1	1	0	1	n.a.	1	1	0	6
Lee et al.	1	1	0	1	1	1	1	1	1	1	7
Loewenstein et al.	1	0	0	0	1	1	1	?	1	1	5
Savage et al.	1	1	1	0	1	1	n.a.	1	1	1	7
Talassi et al.	1	1	0	0	1	1	n.a.	?	?	0	4
Tarraga et al.	1	1	1	0	0	1	1	1	?	1	6
Yamaguchi et al.	1	1	1	0	0	0	?	0	1	0	4
Zaccarelli et al.	1	1	0	1	1	0	n.a.	1	?	0	4
Zhuang et al.	0	?	1	0	0	1	1	?	?	0	3

Note: 1: criterion fulfilled; 0: criterion not fulfilled; ?: unable to determine; n.a. not applicable.

taking into account the stage of dementia and the mood of the participant when planning the treatment.

Meta-analysis

The unit of analysis in the meta-analysis was the change from baseline score. No outliers (more than two SD from the mean of the effect sizes) were identified, thus no studies were excluded for that reason. Outcome measures for cognitive performance, depression, anxiety and activities of daily living used across the studies were pooled for analysis, and the standardised mean differences (SMDs) and 95% confidence intervals (CIs) were calculated.

Effect of the cognitive interventions in cognition of PWD

Figure 2 presents the forest plots of changes of cognition in PWD (measured with MMSE and HDS-R) after the computer-based interventions, pooling data from 7 studies. The effect sizes indicated that PWD got beneficial effects from cognitive interventions (SMD −0.69; 95% CI = −1.02 to −0.37; $P < 0.0001$; $I^2 = 29\%$, fixed-effect model). The total numbers in the pre-test and the post-test studies were 81 (range 7−24).

The meta-analysis of cognitive interventions in case control studies pooled data from five studies with a total of 67 participants in the computer-based interventions and 52 participants in the non-computer-based interventions. It indicated that computer-based cognitive interventions were more beneficial to cognition than non-computer-based interventions (SMD 0.48; 95% CI = 0.09−0.87; $P = 0.02$; $I^2 = 2\%$, fixed-effect model; Figure 3).

Effect of the cognitive interventions in depression and anxiety of PWD

Figure 4 presents the forest plots of change in depression of PWD after a computer-based cognitive intervention. The magnitude of the fixed effect sizes for depression (measured with GDS, CES-D Patient, MOSES Depression and EDC) were within the range of small effect sizes, indicating that people were less depressed after the intervention (SMD 0.47; 95% CI = 0.16 to 0.78; $P = 0.003$; $I^2 = 0\%$, fixed effect model). The total group of the pre-test and the post-test in the six studies was 84 (range 7−24).

The meta-analyses of changes on depression after cognitive interventions in case control studies pooled data from three studies with a total of 26 participants in the non-computer-based interventions. The meta-analysis revealed no significant differences between both groups (SMD −0.02; 95% CI = −0.54 to 0.50; $P = 0.95$; $I^2 = 48\%$, fixed effect model; Figure 5).

Only two studies measured anxiety in participants. Figure 6 presents the forest plots of changes in anxiety after the computer-based cognitive interventions. The magnitude of the fixed-effect sizes for anxiety (measured with STAI State) indicated that anxiety improved after cognitive interventions (SMD 0.55; 95% CI = 0.07 to 1.04; $P < 0.03$; $I^2 = 42\%$, fixed-effect model). The total group of the pre-test and the post-test in the two studies was 34 (range 10−24). Only one study (Talassi et al., 2007) compared the reduction in anxiety of PWD receiving computer and non-computer interventions, thus, no meta-analysis could be conducted. That study did not find significant differences between both groups ($Z = 0.38$, $P = 0.70$).

Effect of the cognitive interventions in activities of daily living of PWD

The meta-analysis revealed no significant changes in activities of daily living in PWD (measured with B-ADLS, AADL, RDRS and Barthel) before and after the computer-based intervention (SMD −0.26; 95% CI = −0.59 to 0.06; $P = 0.11$; $I^2 = 0\%$, fixed-effect model).

Types of studies

Two studies analysed interventions about CRC. In the first one (Loewenstein et al., 2004) the treatment consisted of interactive computer games involving memory, concentration, and problem-solving skills, while the treatment received by the control group consisted of a multimodal rehabilitation programme including computer-based activities. In the second one (Yamaguchi et al., 2011), participants played computer video sports games comprising psychomotor skills based on a brain-activating rehabilitation treatment developed by the authors.

Three of five papers about CR interventions utilised well-structured CR software: neuropsychological training (Cipriani et al., 2006; Talassi et al., 2007) and Big Brain Academy (Fernández-Calvo et al., 2011). The remaining two used a programme simulating a shopping route, which included social competence tasks and tests of orientation and memory (Hofmann et al., 2003), and a teleconference with a therapist

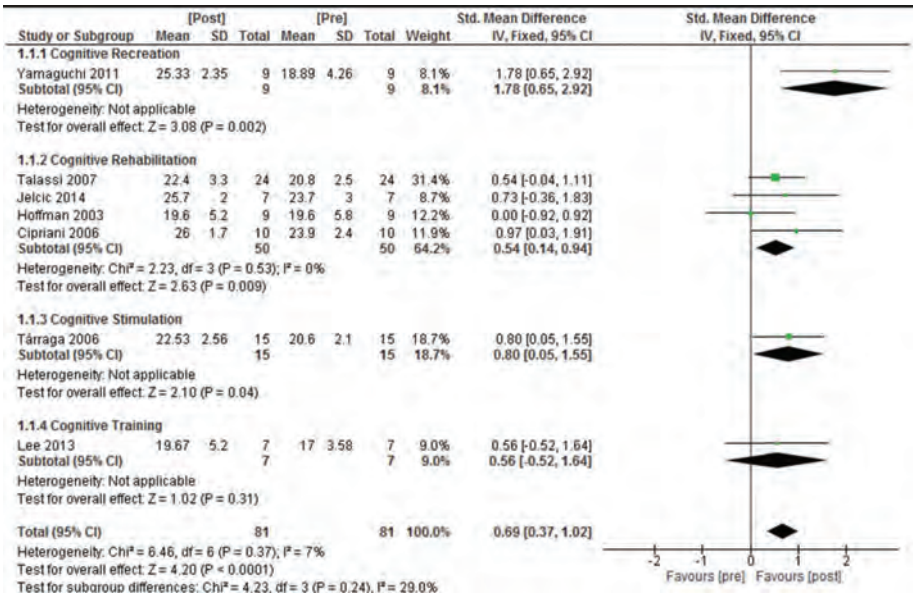

Figure 2. Forest plot of comparisons: change in a global measure of cognition of PWD before and after the computer-based intervention.

providing training on lexical tasks, interpretation of written words and sentences and stories (Jelcic et al., 2014).

Two papers reported interventions of CS (Tárraga et al., 2006; Zaccarelli et al., 2013). In the first study, the experimental group received an interactive multimedia internet-based system (smartbrain) and an integrated stimulation programme, while the control group received only the stimulation programme. In the second study, the experimental group received a programme consisting of CT sessions and social activation; while the control group received no treatment.

Of the three studies about CT, one focused on language and verbal fluency (Savage et al., 2014), one on memory training (Lee et al., 2013) and the other one in memory, language and visuospatial abilities (Zhuang et al., 2013).

Discussion

In this review, we systematically searched for computer-based cognitive interventions for PWD. We identified 12 studies that investigated the effectiveness of four types of interventions (CRC, CR, CS and CT). The meta-analyses indicated that

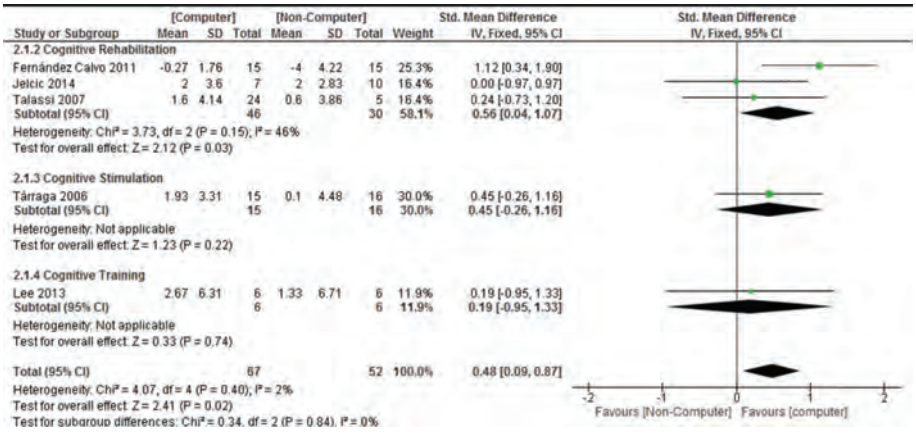

Figure 3. Forest plot of comparisons: computer-based vs. non-computer change in a global measure of cognition.

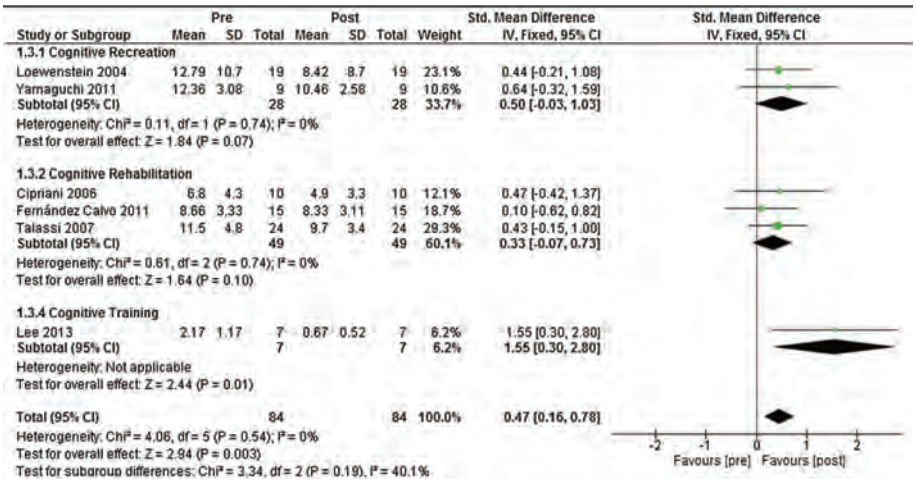

Figure 4. Forest plot of comparisons: change in depression of PWD before and after the computer-based intervention.

computer-based cognitive interventions were associated with significant improvements in cognition, depression and anxiety. No benefits were found for activities of daily living. In studies comparing computer-based interventions with non-computer interventions, the meta-analysis suggested benefits to cognition in favour of the computer-based interventions. No between group differences were identified for depression, anxiety or activities of daily living.

More research is needed to identify the specific factors involved in the better results obtained with computer-based interventions. Hofman et al. (2003) suggested that the design of their intervention may have helped to encourage patients to approach computers, and added that they regarded the computer as a 'status symbol' often associated with youth. Lee et al. (2013) reported that the computer-based intervention enhanced the participants' sense of achievement; as they took pride in showing others that they could operate the computer and were highly motivated.

Six of the studies did not report whether the participants were on pharmacological treatment or not. It would be important that future studies in this area provide that information, as previous literature showed that CR combined with drug treatment in AD is effective (Bottino et al., 2005), and that CS is effective irrespective of whether drugs are prescribed, and any effects are in addition to those associated with the medication (Aguirre, Woods, Spector, & Orrell, 2013). Two of the reviewed studies had a control group with cholinesterase inhibitors only (Loewenstein et al., 2004; Tárraga et al., 2006), showing that the combined treatment is more effective than drugs only.

Dementia care often requires a wide range of interventions to help maximise the patient's independence and autonomy, increasing their self-confidence and relieving burden to the carer (Aguirre et al., 2013; Tárraga et al., 2006). Those should include social inclusion and social activation, specifically targeting increasing social interactions, and helping PWD to live meaningful lives. A strong social network has been suggested to decrease the risk of dementia due to social interaction and mental stimulation (Wang, Karp, Winblad, & Fratiglioni, 2002). As previous evidence suggests that CS is more effective than CR and CT in paper and pencil interventions (Huntley, Gould, Liu, Smith, & Howard, 2015), it would be useful to carry out comparative studies to investigate if that is also the case in computer-based interventions.

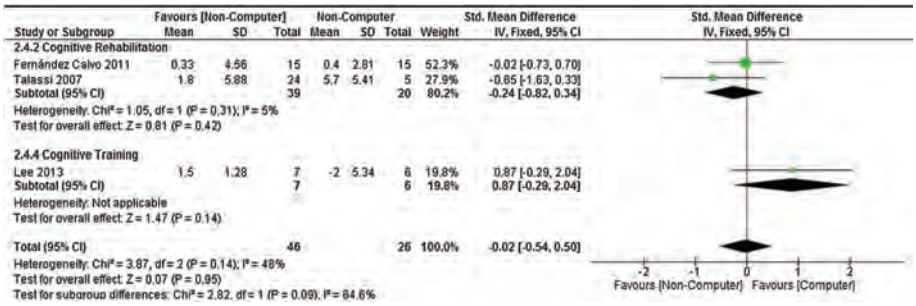

Figure 5. Forest plot of comparisons: computer-based vs. non-computer change in depression.

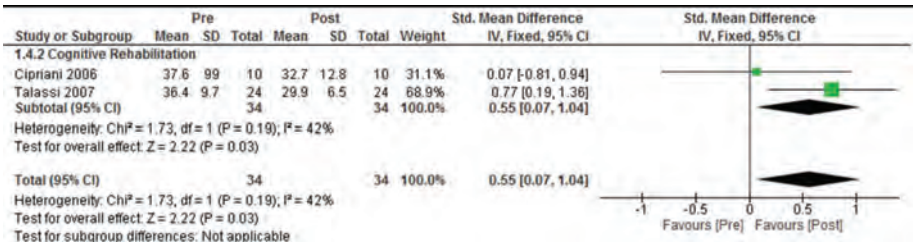

Figure 6. Forest plot of comparisons: change in anxiety of PWD before and after the computer-based intervention.

The lack of studies in the domain of CRC might be explained by the absence of knowledge until recently about the potential protective factor of leisure computer use over cognitive decline. In the past, the participation in regular leisure activities has been associated with a reduced risk of dementia (Verghese et al., 2003). Thus, specific studies about computer-based leisure activities and their impact on cognitive functions should be carried out, as the population beyond the digital gap is aging and is increasingly using social media. Peretz et al. (2011) investigated whether personalised computerised CT provided greater benefits than those obtained by playing conventional computer games. They concluded that it appeared to be more effective than games in improving cognitive performance in healthy older adults (Peretz et al., 2011). The participants who only played games also improved in some cognitive areas, but not as much as those who participated in the CT programme. An initial analysis of the data set of the ELSA indicated that the use of email/internet may reduce cognitive decline (Xavier et al., 2014). These results suggest that as ELSA shows, leisure computer use of the internet and e-mail might protect against cognitive decline; computer-based cognitive interventions build on this.

Multimodal intervention results (Talassi et al., 2007; Tárraga et al., 2006) suggest that there is an added value to the inclusion of computer-based interventions in multicomponent treatments. In the study by Tarragá et al. (2006), the intervention was a high dosage integrated stimulation programme. Still, the addition of only 15 to 24 minutes of computer-based CR three times a week improved cognitive performance in the participants.

Studies comparing PWD with other populations (Cipriani et al., 2006; Talassi et al., 2007; Zaccarelli et al., 2013; Zhuang et al., 2013), reported different types of effects in both groups which might suggest a specific effect of treatment in PWD, reinforcing the need to carry out specific research with this population, since findings from studies of healthy older adults and MCI should not be extrapolated to PWD. Studies like the one published by Owen et al. (2010) can be misleading, as they assessed the efficacy of computer-based CT in regard to generalisability, while their main effect when it comes to PWD would be in the field of prevention, as a protective factor. We did not find specific papers for people with early onset dementia. As this population have specific needs and characteristics, and might be keener on using ICT, future directions in research should carry out specific studies in this area.

Method problems and bias

The quality of the methodology of the studies was acceptable according to Downs & Black criteria, the weakest methodological area being the external validity, with most of the studies failing to assess if the participants were representative of the entire population from which they were recruited. The diversity of the studies and the difficulty in standardising a treatment dose made it impossible to analyse the best treatment characteristics, limiting the ability of researchers to evaluate the evidence base, and highlighting the need for a more consistent approach from different researchers in order to obtain better quality evidence. One of the strengths of the computer-based interventions is that, most of them are based upon standardised programmes and they usually have a treatment protocol, making their clinical implementation more likely to be replicated in controlled conditions. The fact that eight of them reported on performance according to protocol, shows that it is possible to deliver a standardised treatment and to report exceptions and changes, as most of the information can be registered by the programme itself. Researchers have made an effort to address the issue of generalisability in their interventions, probably because it has been one of the criticisms that cognitive interventions in dementia in general, and computer-based interventions in particular, have received. However, results were disperse and impossible to compare. Specific outcome measures in this area should be developed for computer-based cognitive interventions in PWD.

Limitations

The conclusions drawn from this review must be considered in the context of some limitations. First, this review contained a small number of RCTs. Although RCTs produce the strongest conclusions in terms of efficacy, we decided to include other types of studies for the sake of obtaining a wider panorama of the state of the art in this area. Second, the studies consisted of heterogeneous interventions and designs, making the comparison of outcomes difficult. However, we tried to overcome this hurdle by assessing the quality of the studies and pooling relevant data for meta-analyses. Finally, we would have liked to include specific cognitive domains, but the diversity of the studies was such that it was not feasible.

Conclusion

We can conclude that computer-based cognitive interventions have a moderate effect on cognition and anxiety and a small effect on depression in PWD. Computer based cognitive interventions lead to better results than non-computer based interventions in cognition. There is insufficient evidence to support that this interventions improve activities of daily

living. Further research is needed on all four types of interventions, particularly in the overlooked areas of computer-based CRC, and in the undeveloped area of computer-based CS. There is also a need for longer-term follow-up to examine the retention of treatment effects, and for the design of specific outcome measures. Most importantly what we need are high-quality RCTs.

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Disclosure of interests

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Annex 1. Search terms combination cascade.

(Dementia or Alzheimer) + (cognitive or memory or reality orientation or stimulation or rehabilitation or training) + (computer or technology or telerehabilitation). We decided not include 'activity' in our search terms as it proved to be too generic.

Dementia + cognitive + computer
Dementia + cognitive + computing
Dementia + cognitive + technology
Dementia + cognitive + telerehabilitation
Dementia + memory + computer
Dementia + memory + computing
Dementia + memory + technology
Dementia + memory + telerehabilitation
Dementia + reality orientation + computer
Dementia + reality orientation + computing
Dementia + reality orientation + technology
Dementia + reality orientation + telerehabilitation
Dementia + stimulation + computer
Dementia + stimulation + computing
Dementia + stimulation + technology
Dementia + stimulation + telerehabilitation
Dementia + rehabilitation + computer
Dementia + rehabilitation + computing
Dementia + rehabilitation + technology
Dementia + rehabilitation + telerehabilitation
Dementia + training + computer
Dementia + training + computing
Dementia + training + technology
Dementia + training + telerehabilitation

Alzheimer + cognitive + computer
Alzheimer + cognitive + computing
Alzheimer + cognitive + technology
Alzheimer + cognitive + telerehabilitation
Alzheimer + memory + computer
Alzheimer + memory + computing
Alzheimer + memory + technology
Alzheimer + memory + telerehabilitation
Alzheimer + reality orientation + computer
Alzheimer + reality orientation + computing
Alzheimer + reality orientation + technology
Alzheimer + reality orientation + telerehabilitation
Alzheimer + stimulation + computer
Alzheimer + stimulation + computing
Alzheimer + stimulation + technology
Alzheimer + stimulation + telerehabilitation
Alzheimer + rehabilitation + computer
Alzheimer + rehabilitation + computing
Alzheimer + rehabilitation + technology
Alzheimer + rehabilitation + telerehabilitation
Alzheimer + training + computer
Alzheimer + training + computing
Alzheimer + training + technology
Alzheimer + training + telerehabilitation