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Title:

The Impact of Cognitive Training and Mental Stimulation on Cognitive and Everyday Functioning of Healthy Older Adults: A Systematic Review and Meta-Analysis

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Abstract

This systematic review and meta-analysis investigates the impact of cognitive training and general mental stimulation on the cognitive and everyday functioning of older adults without known cognitive impairment. We examine transfer and maintenance of intervention effects, and the impact of training in group versus individual settings. Thirty-one randomised controlled trials were included, with 1,806 participants in cognitive training groups and 386 in general mental stimulation groups. Meta-analysis results revealed that compared to active controls, cognitive training improved performance on measures of executive function (working memory, $p=0{\cdot}04$; processing speed, $p<0{\cdot}0001$) and composite measures of cognitive function ($p=0.001$). Compared to no intervention, cognitive training improved performance on measures of memory (face-name recall, $p=0{\cdot}02$; immediate recall, $p=0{\cdot}02$; paired associates, $p=0{\cdot}001$) and subjective cognitive function ($p=0.01$). The impact of cognitive training on everyday functioning is largely under investigated. More research is required to determine if general mental stimulation can benefit cognitive and everyday functioning. Transfer and maintenance of intervention effects are most commonly reported when training is adaptive, with at least ten intervention sessions and a long-term follow-up. Memory and subjective cognitive performance might be improved by training in group versus individual settings.

Keywords

Systematic review; meta-analysis; cognitive training; mental stimulation; cognitive functioning; healthy older adults.

1. Introduction

Cognitive impairment that does not reach the threshold for dementia diagnosis is not only associated with increased risk for progression to dementia (Fratiglioni and Qiu, 2011; Petersen, 2004; Winblad et al., 2004), but also increased health care costs (Albert et al., 2002), increased neuropsychiatric symptoms (Lyketsos et al., 2002), and increased functional disability (McGuire et al., 2006). Age-related decline in episodic memory, attention, and executive function is reported in both longitudinal (Meijer et al., 2009; Tucker-Drob et al., 2009) and cross-sectional studies (Coubard et al., 2011; Kray and Lindenberger, 2000). Decline in executive function is also associated with impaired functioning in activities of daily living (Royall et al., 2000). The high prevalence of cognitive impairment with advancing age (Plassman et al., 2008), together with rapid demographic ageing, underlines the importance of developing interventions to improve or maintain cognitive function in later life.

Interventions comprising modifiable lifestyle factors, such as cognitive, social, and physical activity, that may reduce the risk of cognitive decline have been gaining increasing interest (Coley et al., 2008; Mangialasche et al., 2012). Of these strategies, cognitive interventions are specifically targeted at improving cognitive performance. In the research literature, cognitive interventions for older adults without known cognitive impairment are delivered either in group or individual settings, and consist of either (i) cognitive training or (ii) general mental stimulation.

Cognitive training comprises specifically designed training programs that provide guided practice on a standard set of cognitive tasks, aimed at improving performance in one or more cognitive domains (Martin et al., 2011). While a number of randomised controlled trials (RCTs) have shown that cognitive training can improve cognitive performance in healthy older adults (Reijnders et al., 2012), improvements often do not exceed those seen in active control conditions (Martin et al., 2011). Furthermore cognitive training can lack ecological validity, with little evidence of generalizability to everyday cognitive tasks (Papp et al., 2009). In light of these limitations, cognitive interventions comprising general mental stimulation may present a promising alternative.

General mental stimulation refers to interventions that promote increased engagement in mentally stimulating activities. Examples include activities that might be undertaken by individuals as part of daily living; for example, reading, playing music or playing chess.

Epidemiological evidence suggests that higher levels of engagement in mental stimulation are associated with lower rates of cognitive decline (Scarmeas et al., 2001; Wilson et al., 2002a; Wilson et al., 2002b; Wilson et al., 2007), with less decline specifically noted in working memory and processing speed (Wilson et al., 2002b). However most of the evidence to date is correlational and only a limited number of RCTs have examined the efficacy of mental stimulation on cognition. A further difficulty is that either mental stimulation RCT's are not included in reviews of cognitive interventions, or reviews consider cognitive training and mental stimulation as one; making it difficult to determine the relevant effects of either intervention (Papp et al., 2009; Reijnders et al., 2012; Tardif and Simard, 2011).

There are several relevant criteria emerging from the literature that support the efficacy of cognitive interventions. Effective interventions can be considered in terms of improvements in performance on targeted cognitive tasks, maintenance of improved performance over time, transfer of training effects to different tasks within the same cognitive domain (near transfer) or other domains (far transfer), and generalisation of effects to everyday functioning. (Klingberg, 2010; Martin et al., 2011). Maintenance; or the temporal durability of training effects after the intervention has ceased, has been reported in several RCTs of cognitive training (Rebok et al., 2007; Reijnders et al., 2012; Verhaeghen, 2000), however evidence for transfer is somewhat limited (Owen et al., 2010; Papp et al., 2009). If transfer is reported, it is often only to untrained tasks within the same cognitive domain (Kueider et al., 2012; van Muijden et al., 2012; West, 2000). Generalisation of training effects to everyday functioning is of particular importance if cognitive interventions are to impact older adults' cognition and independence in a meaningful way. Evidence for generalisation is limited however, as cognitive intervention RCT's and reviews rarely include everyday functioning as an outcome measure (Martin et al., 2011).

The aim of this paper is to update the extant literature, and to address shortcomings noted in prior reviews. We examine existing evidence from RCT's of cognitive interventions to determine the impact of both cognitive training and general mental stimulation on the cognitive performance of older adults without known cognitive impairment. We also investigate the potential of cognitive interventions to promote transfer and maintenance of intervention effects, discuss generalisation of cognitive interventions to everyday functioning, and explore whether training in a group has any added benefit over training in individual settings.

2. Methods

2.1. Search strategy

We searched the databases PubMed, Medline, the Cochrane Library, and ClinicalTrials.gov to identify randomised controlled trials written in English and published between 2002 and 2012. Search terms included "cognitive intervention", "cognitive training", "cognitive stimulation", "cognitive rehabilitation" , "brain training", "memory training", "mental stimulation", and "healthy elderly", "older adults", "ageing", "cognitive ageing", "cognitively healthy" OR "cognition" (full search strategy, appendix A). We supplemented database searches with reference lists in review papers, authors' own files, and Google Scholar. We screened titles and abstracts to exclude articles that did not meet inclusion criteria. Full texts of remaining studies were then screened for eligibility by two independent reviewers, with disagreements resolved through discussions with our expert authors (study selection flowchart, appendix B).

2.2. Selection criteria

We followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Trials were included that investigated the effects of <u>either</u> cognitive training <u>or</u> general mental stimulation interventions on cognitive function in community dwelling older adults (>50) with no known existing cognitive impairment. Studies required at least ten participants per condition. We excluded studies if participants had been diagnosed with any cognitive impairment, cardiovascular disease, or other significant medical, psychiatric, or neurological problems (see excluded studies table, appendix C). The risk of bias in individual studies was assessed by two independent reviewers (appendix D) using guidelines outlined in Section 8 of the Cochrane Handbook.

Our primary outcomes of interest were cognitive and everyday functioning. In line with a recent Cochrane review (see Martin et al., 2011) cognitive outcome measures were grouped into separate ability subgroups within each cognitive domain. This allowed for the pooling of data that were deemed as homogeneous as possible. Within the memory domain, outcomes were grouped according to the ability subgroups of recognition, immediate recall, delayed recall, face-name recall, and paired associates. Within the executive functioning domain, outcomes were grouped according to the ability subgroups of working memory, verbal fluency, reasoning, attention and processing speed. Composite measures of cognitive function were also included. A secondary outcome of interest was subjective measures of cognitive performance.

2.3. Statistical Analysis

Data extraction was conducted by two independent reviewers and cross-checked by a member of the expert panel. We used Review Manager Version 5.1 software for Windows to conduct the analysis. We calculated treatment effects based on pooled data from individual trials that were deemed homogenous. All trials reported outcomes as continuous data. The summary statistics required for each outcome were the number of participants in intervention and control groups at baseline and post-test, the mean change from baseline and the standard deviation (SD) of the mean change. If change-from-baseline scores were not provided, they were calculated using baseline and post-test mean and SD's. Change SD's were calculated assuming zero correlation between the measures at baseline and follow-up. Although this method may overestimate the SD of the change from baseline, it is a conservative approach which is preferable in a meta-analysis (Higgins, 2011). As pooled trials used different rating scales or tests, the summary measure of treatment effect was the standardised mean difference (SMD - the absolute mean difference divided by the standard deviation). Where trials used the same rating scale or test, the weighted mean difference was calculated. Individual effect sizes were combined using the inverse variance random-effects method (DerSimonian and Laird, 1986). This was used to allow the incorporation of heterogeneity among studies. Statistical heterogeneity was assessed by the I^2 test, which describes the percentage of variability among effect estimates beyond that expected by chance. Overall estimates of the treatment difference are presented in forest plots (figures 1–5). As it was not possible to pool data from all included studies, a summary of results from individual trials are outlined and presented in tables 1–5.

3. Results

3.1. Included Studies

Thirty-one randomised controlled trials were eligible for inclusion, with 1,806 participants in cognitive training experimental groups, 386 in general mental stimulation experimental groups, 1,541 'no intervention' controls and 822 active controls. The most common cognitive training intervention was memory-based training. Mental stimulation interventions were diverse and included activities such as playing piano, acting, and helping children with reading difficulties. The 'no intervention' controls received either no contact, minimum social support, or were placed on a waiting list. Active control groups included educational DVDs or lectures, health-promotion training, non-brain training computer games, or some form of unstructured learning. Study characteristics are presented in Tables 1-5.

3.2. Cognitive training

3.2.1. Cognitive training versus 'no intervention'

Meta-analysis results (figure 1) revealed that compared to 'no intervention' controls, cognitive training significantly improved performance on the memory measures of face-name recall (p=0·02), immediate recall (p=0·02), and paired associates (p=0·001), and on subjective measures of cognitive performance (p=0·01). There were no significant differences between the groups in the memory measures of recognition (p=0·29), and delayed recall (p=0·29), or in the executive measure of working memory (p=0·20). Data were not available for the remaining outcomes of interest: verbal fluency, reasoning, attention and processing speed in the executive domain; composite measures of cognitive function and everyday functioning.

In individual studies (table 1), significant improvements were reported for cognitive training compared to no intervention in 19 of 26 memory outcome measures (Bailey et al., 2010; Bottiroli and Cavallini, 2009; Buiza et al., 2008; Cavallini et al., 2010; Cheng et al., 2012; Craik et al., 2007; Edwards et al., 2002; Fairchild and Scogin, 2010; Hastings and West, 2009; Jackson et al., 2012; Mahncke et al., 2006; Valentijn et al., 2005), in seven out of 16 measures of executive function (Ball et al., 2002; Buiza et al., 2008; Cheng et al., 2012; Craik et al., 2007; Edwards et al., 2002; Jackson et al., 2012; Mahncke et al., 2006; Margrett and Willis, 2006), and on both composite measures of cognitive function (Cheng et al., 2012; Mahncke et al., 2006). One trial found that reasoning training resulted in less self-reported decline in everyday functioning compared to control (Ball et al., 2002; Willis et al., 2006). For secondary outcomes, significant improvements were reported for training versus control in four out of six measures of subjective cognitive performance (Fairchild and Scogin, 2010; Hastings and West, 2009; Valentijn et al., 2005). Transfer of training effects were recorded in five out of seven trials: four reported transfer to untrained tasks within the same domain (Bottiroli and Cavallini, 2009; Cavallini et al., 2010; Cheng et al., 2012; Mahncke et al., 2006), one to other cognitive domains (Cheng et al., 2012), and one to everyday functioning (Ball et al., 2002). All seven trials that included follow-up assessments reported maintenance of training effects (Ball et al., 2002; Buiza et al., 2008; Cheng et al., 2012; Craik et al., 2007; Hastings and West, 2009; Mahncke et al., 2006; Valentijn et al., 2005).

3.1.2. Cognitive training versus active control

Compared to active controls, cognitive training interventions significantly improved performance on the memory measure of recognition (p<0·0001), on the executive measures of working memory (p=0·04) and processing speed (p<0·0001) and also on composite measures of cognitive function (p=0·001). Effects for subjective cognitive performance approached significance (p=0·07). There were no significant differences between the two groups in measures of immediate recall (p=0·35), delayed recall (p=0·84), or attention (p=0·43) (figure 2). Data were not available for face-name recall, paired associates, verbal fluency, reasoning, or everyday functioning.

In individual studies (table 2), significant improvements for intervention groups were reported in seven out of 15 memory outcome measures (Legault et al., 2011; Mahncke et al., 2006; Mozolic et al., 2011; Peretz et al., 2011; Richmond et al., 2011; Smith et al., 2009), 17 out of 29 measures of executive function (Borella et al., 2010; Carretti et al., 2012; Legault et al., 2011; Mahncke et al., 2006; Mozolic et al., 2011; Nouchi et al., 2012; Peretz et al., 2011; Richmond et al., 2011; Smith et al., 2009), and six out of nine composite measures of cognitive function (McDougall et al., 2010). None of the studies included measures of everyday functioning. For secondary outcomes, significant improvements were reported for training versus control in three out of four subjective measures of cognitive performance (McDougall et al., 2010; Richmond et al., 2011; Smith et al., 2009). Transfer of training effects were reported in nine out of ten trials: five reported transfer to untrained tasks within the same domain (Borella et al., 2010; Carretti et al., 2012; Mahncke et al., 2006; Nouchi et al., 2012; Peretz et al., 2011) and six to other cognitive domains (Borella et al., 2010; Carretti et al., 2012; McDougall et al., 2010; Mozolic et al., 2011; Richmond et al., 2011; Smith et al., 2009). Four out of five trials that included follow-up assessments reported maintenance of training effects (Borella et al., 2010; Carretti et al., 2012; Mahncke et al., 2006; Smith et al., 2009).

3.3. Mental stimulation

3.3.1. Mental stimulation versus 'no intervention'

Due to heterogeneity and a lack of available data, it was not appropriate to conduct a meta-analysis. In individual trials we found that mental stimulation groups significantly outperformed 'no intervention' controls on four out of eight memory measures (Carlson et al., 2008; Klusmann et al., 2010; Noice and Noice, 2009; Slegers et al., 2009), nine out of 17 measures of executive function (Basak et al., 2008; Bugos et al., 2007; Carlson et al., 2008; Klusmann et al., 2010; Noice and Noice, 2009; Slegers et al., 2009; Tesky et al., 2011), and one out of three composite measures of cognitive function (Slegers et al., 2009; Tesky et al., 2011; Tranter and Koutstaal, 2008). The trials did not include measures of everyday functioning. There were no differences between the groups on two measures of subjective cognitive performance (Slegers et al., 2009; Tesky et al., 2011). Each of the mental stimulation interventions resulted in a transfer of effects to at least one cognitive outcome measure (table 3). Neither trial that included follow-up assessments reported maintenance of intervention effects (Bugos et al., 2007; Slegers et al., 2009).

3.3.2. Mental stimulation versus active control

Three of the above trials also compared mental stimulation to an active control. As above, it was not deemed appropriate to conduct a meta-analysis. In individual trials, Klusmann and Slegers reported no significant differences between mental stimulation and active control groups on four measures of memory, four measures of executive function, one composite measure of cognitive function and one measure of subjective cognitive performance (Klusmann et al., 2010; Slegers et al., 2009). Noice et al. found that acting class participants significantly outperformed singing class controls in two measures of memory and two measures of executive function (Noice and Noice, 2009). None of the studies included measures of everyday functioning.

3.4. Training in group versus individual settings

Only data from Hastings and Valentijn could be pooled for meta-analysis (figure 3). Results revealed that participants who took part in group cognitive training sessions were more likely to self-report their memory as better than those who trained in individual settings ($Z=0{\cdot}97$) although the effect was not significant ($p=0{\cdot}14$). There was no difference between the groups on immediate recall performance ($p=0{\cdot}87$). It was not possible to pool data for any of the remaining primary or secondary outcome measures of interest.

In individual trials, those who trained in groups performed significantly better on three out of six measures of memory (table 5). There were no differences between the groups on three measures of executive function (Hastings and West, 2009; Margrett and Willis, 2006; Valentijn et al., 2005), or on four out of five measures of subjective cognitive performance (Hastings and West, 2009; Valentijn et al., 2005). However, participants who completed training within a group had significantly higher ratings of memory self-efficacy (Hastings and West, 2009). Significant intervention effects for memory self-efficacy (Hastings and West, 2009) and delayed recall were maintained at follow-up (Valentijn et al., 2005). There were no differences in transfer effects.

4. Discussion

Compared to no intervention, cognitive training improved performance on measures of memory (face-name recall, immediate recall, paired associates) and subjective cognitive function. Compared to active controls, cognitive training improved performance on measures of executive function (working memory, processing speed) and composite measures of cognitive function. In individual trials, mental stimulation improved performance on measures of memory, executive function, and on composite measures of cognitive function but these results were not consistent across trials. Training in group versus individual settings improved memory and subjective cognitive performance.

4.1. Cognitive training

Meta-analysis results revealed that compared to no intervention, cognitive training significantly improved performance on the memory measures of immediate and delayed recall, but this effect was not observed when the training condition was compared to an active control. This conclusion is consistent with findings from two prior reviews which reported that although cognitive training enhanced memory performance, improvements were generally not specific to the intervention (Martin et al., 2011; Zehnder et al., 2009). Taken together, these results indicate that engaging in mentally stimulating activities, as active control participants did, may benefit memory performance as much as cognitive training. RCT's directly comparing the effects of mental stimulation and cognitive training on memory performance would be beneficial to determine whether cognitive training is necessary to improve memory, or if increasing general mental stimulation could suffice. General mental stimulation might be easier to incorporate into ones daily routine, and could present a more ecologically valid alternative to cognitive training.

We found that cognitive training significantly improved performance on measures of recognition, on composite measures of cognitive function, and on executive measures of working memory, and processing speed compared to active controls. Consistent with our findings, previous reviews have reported significant intervention effects for cognitive training versus active controls on cognition, particularly on measures of executive functioning (Reijnders et al., 2012; Tardif and Simard, 2011). Larger effect sizes have been reported for executive measures of reasoning and processing speed compared to measures of memory (Papp et al., 2009). Cognitive training may therefore have task-specific benefits for executive functioning. At present, many trials and reviews limit their focus to memory outcomes alone (Zehnder et al., 2009).Our results however indicate that executive outcome measures should be included to provide more definitive evidence on the effects of cognitive training on executive outcomes.

4.2. Mental stimulation

Significant intervention effects were reported for mental stimulation versus no intervention controls in four out of eight measures of memory, nine out of 17 measures of executive function, and on one out of three composite measures of cognitive function. A low number of mental stimulation RCT's, combined with varied intervention-types and outcome measures rendered pooling of data either inappropriate or impossible. To support meta-analyses in mental stimulation intervention trials, two key areas need to be addressed. Firstly, a greater number of RCT's are required to allow for more pooling of data. In this review for example, there were only 386 participants in mental stimulation groups compared to 1,806 in cognitive training groups. If participant numbers for mental stimulation trials were comparable to those in cognitive training trials, it would allow for more definitive conclusions to be drawn on optimal intervention-types. Secondly, researchers of general mental stimulation would benefit from agreement on a standard set of guidelines on intervention designs and outcome measures. For example, Noice and Noice (2009) identified two specific elements of mental stimulation that might be responsible for cognitive gains: novelty and multi-modal stimulation. They incorporated these elements into their mental stimulation intervention and reported consistent positive intervention effects. For outcome measures, they provided a rationale for their choice of instruments which may be used as a guide for others. For example, they included instruments that tested cognitive abilities deemed important for independent living, could be administered in a single session of less than 90 minutes, and that were most commonly utilised in the field. Such standardisation would allow for comparability of results across individual trials and more pooling of data.

Overall, our review shows that mental stimulation might benefit cognitive function of older adults, but these results are not consistent across trials. One possible explanation for a lack of consistent results may be due to insufficiently long follow-up periods. Evidence from observational and longitudinal studies, that consistently report a protective effect of mental stimulation on cognition, suggests that mental stimulation might operate by maintaining cognitive function over time, as opposed to immediately improving performance (Albert et al., 2002; Wang et al., 2012). Trials of short duration may not, therefore, be appropriate to measure intervention effects. Mental stimulation trials could perhaps be modelled on the ACTIVE trial (Willis et al., 2006) that included a 5-year follow-up. This might be relevant as

ACTIVE researchers noted that only after the onset of decline in the control group could the positive training effects on function be observed in the intervention groups.

4.3. Transfer and maintenance

Contrary to prior reports (Owen et al., 2010; Papp et al., 2009) 21 trials included in this review reported transfer of cognitive intervention effects. Similar to other findings (Kueider et al., 2012; Papp et al., 2009; van Muijden et al., 2012; West, 2000), training most reliably produced transfer to tasks within the same cognitive domain, although seven cognitive training studies also reported transfer to untrained cognitive domains (Ball et al., 2002; Borella et al., 2010; Carretti et al., 2012; Cheng et al., 2012; Mozolic et al., 2011; Richmond et al., 2011; Smith et al., 2009). Consistent with research reporting that transfer depends on the type and duration of training (Klingberg, 2010; Owen et al., 2010; van Muijden et al., 2012), interventions using adaptive and repetitive training sessions (Borella et al., 2010; Carretti et al., 2012; Mozolic et al., 2011; Richmond et al., 2011; Smith et al., 2009) or longer training periods (Cheng et al., 2012; Richmond et al., 2011; Smith et al., 2009) were most likely to produce far transfer.

Maintenance was reported in nine out of ten cognitive training interventions, lasting between 3 and 6 months. These findings are consistent with reports from other reviews that training effects can be preserved for at least a couple of months in both memory and executive domains (Reijnders et al., 2012; Verhaeghen, 2000). Results from included studies reporting longer-term maintenance support suggestions (Klingberg, 2010; Rebok et al., 2007) that maintenance may require booster sessions or an adaptive training paradigm (Borella et al., 2010; Cheng et al., 2012; Willis et al., 2006), with at least ten intervention sessions (Cheng et al., 2012; McDougall et al., 2010).

4.4. Generalisation to everyday functioning

The primary difficulty in determining the impact of cognitive interventions on the everyday functioning of healthy older adults is that most trials do not include functional outcome measures (Reijnders et al., 2012; Tardif and Simard, 2011). Only two of the included studies in this review examined the effects of cognitive training on everyday function (Ball et al., 2002; McDougall et al., 2010). McDougall found that six-months of memory training did not significantly improve everyday functioning for older adults at a 2-year follow-up. Ball et al. (2002) similarly reported no training effects on everyday functioning after 6-weeks of memory training, reasoning training or processing speed training at a 2-year follow-up.

Interestingly however, Ball and colleagues later conducted a 5-year follow-up, and found that inductive reasoning training (in the executive domain), predicted a significant proportion, and the most variance, in baseline everyday functioning. They concluded that successful performance in everyday tasks is critically dependent on executive cognitive function (Gross et al., 2011).

These results are supported by prior research that shows that the ability to perform independent living skills is dependent on intact executive function (Cahn-Weiner et al., 2002; Dodge et al., 2006; Johnson et al., 2007; Royall et al., 2007), and that reasoning may be of particular importance as it influences problem-solving related to cognitively demanding everyday tasks (Burton et al., 2006; Willis et al., 1998). As both mental stimulation (Wilson et al., 2002b) and cognitive training (Ball et al., 2002) have been shown to benefit executive function, these interventions might be important for improving or maintaining everyday functioning of older adults. These findings should certainly guide future cognitive intervention programmes. Importantly, follow- up periods longer than 2-years may also be required to detect benefits of executive training on functional abilities, as positive training effects in intervention groups might only be observed after the onset of decline in the control group (Willis et al., 2006).

4.5. Training in group versus individual settings

We found no significant differences between participants who trained in group versus individual settings on measures of delayed recall or subjective performance. In individual trials, those who trained in groups (relative to those who trained on an individual basis) performed significantly better on 50% of memory measures, had significantly higher ratings of memory self-efficacy, and reported more stability and less anxiety about memory functioning (Valentijn et al., 2005). These results are supported by research that shows that cognitive interventions produce maximum benefits when participants trained in groups (Verhaeghen et al., 1992). Researchers have suggested a number of possible explanations: Training in a group setting can provide participants with an opportunity to problem-solve with a relevant peer group (Verhaeghen et al., 1992), can motivate group members to practise effective strategies (Saczynski et al., 2004), and allows individuals to gain comfort from sharing their concerns about memory (Flynn and Storandt, 1990). These types of social influences not only increase motivation and problem-solving, but have also been shown to increase self-efficacy (Bandura, 1989). This may in turn contribute to cognitive performance as increased self-efficacy is shown to produce improved and longer lasting effects of cognitive interventions (Bandura, 1993; West et al., 2003). Those designing cognitive interventions should develop group programmes where possible to ensure participants can avail of peer support and engagement which might also positively influence cognition.

4.6. Limitations of the review

By only including published data we risked the possibility of overestimating intervention effects; although concerns about publication bias may be somewhat mitigated by the fact that four of the included trials were published despite no overall evidence for any intervention effect (Craik et al., 2007; Legault et al., 2011; Slegers et al., 2009; Tesky et al., 2011). Also, a 2012 cognitive intervention review searched for unpublished data and found only studies that were either non-randomised or completed prior to 2002, and thus would have been excluded from this review (Kueider et al., 2012). Nevertheless caution should be taken when interpreting intervention effects. The most notable limitation was the variation in methodologies and cognitive measures across trials. This made conducting a meta-analysis quite difficult. Although we made a distinct effort to only combine homogenous data, it was necessary to compromise on the heterogeneity of included studies in some of the analyses. Issues with methodological differences are commonly reported (Kueider et al., 2012; Martin et al., 2011; Zehnder et al., 2009), further highlighting the need for standardisation in cognitive intervention trials.

4.7. Conclusions/ recommendations

Overall, we found that cognitive training interventions were effective in improving memory and subjective measures of cognitive performance relative to no intervention, and composite measures of cognitive function and executive functions relative to active controls. More research is required to determine the possible benefits of general mental stimulation. If cognitive interventions are to benefit everyday functioning, training should target improvements in executive function. To improve the likelihood of transfer and maintenance of intervention effects, cognitive training programs should be adaptive with at least ten intervention sessions and include a long-term follow-up. Training conducted in group settings may have additional benefits for objective and subjective cognitive performance over training in individual settings. Standardised training protocols and outcome measures are required to allow for more pooling of homogenous data, and to confirm the optimal type and dose of cognitive interventions.

Conflicts of interest

All authors declare that we have no conflicts of interest.

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Table 1
Characteristics of Studies - Cognitive Training vs. No Intervention Control

Ref. Author (year)	Intervention	Methods	Participants	Outcomes of Interest	Generalisation/ Maintenance
Bottiroli (2009)	Computer-based memory training vs. control	Standard RCT design Trained 2 memory strategies in 3 sessions FU: PT	EG: 21 CG: 23 Age: 58 – 83	Recognition[a] Face-name recall[a] Paired associates[a]	Training generalised to near transfer tasks
Craik (2007)	Effects of a multi modular cognitive rehabilitation programme. Memory training module vs. control	Within subject cross-over RCT 12 weeks FU: PT and 6 months	EG: 29 CG:20 Age: 71 - 87	Immediate recall[a] Recognition[c] Primary memory[c] Delayed recall[c] Story Recall[c] Working Memory[c]	Sig improvement from BL to 6 month FU on total words recalled for experimental, not control.
Jackson (2012)	Investigating if intervention to increase cognitive ability can also increase openness to experience. Inductive reasoning training vs. control	RCT 16 weeks training (ran over 22weeks) Also 2x 1hr classroom sessions FU: PT	EG:78 CG:88 Age: 60 - 94	Inductive Reasoning[a] Divergent thinking[c] Processing speed[c] Verbal Ability[c]	No transfer to other cognitive abilities
Mahncke (2006)	Evaluating a brain-plasticity based training program. Computer based training vs. control	Double blind RCT 8-10 weeks of training FU: PT and 3 months	EG: 53 CG:56 Age: 60 - 87	Recognition[b] Working memory[b] Speed of processing[b] Global auditory memory[b]	Near transfer of improvements to RBANS memory & digit span; improvement in memory & digit span maintained at 3month FU
Buiza (2008)	Investigating a new cognitive therapy. Structured cognitive training vs. control	Double-blind RCT 2 years (180 sessions) FU: PT, 1 year, 2 years PT	EG1: 85 CG: 85 Age: >65	Immediate memory[a] Working Memory[a] Verbal Fluency[a] Short term memory[c]	Significant improvement in imm memory & fluency maintained at 2yr FU, not observed in cntrl. Transfer not measured.
Cavallini (2010)	Instruction based mnemonics strategy training vs. control	Standard RCT design 4 sessions of 2hrs FU: PT	EG: 27 CG: 29 Age: 57 - 81	Paired associates[a] List recall[a] Text recall[a] Face name recall[c]	Sig improvement in one of two near transfer tasks
Cheng (2012)	Multi-domain training (MDT) vs. single domain training (SDT) vs. control	Double-blind RCT 2x per week for 12 weeks FU: PT, 6 month, 12 month	EG: 54 CG: 60 Age: 65 – 75	Immediate recall[b] Delayed recall[a] Visual reasoning[a] Attention[c] Speed of Processing[c] Cognitive function[a]	MDT near transfer to untrained tasks, SDT far transfer. Cognitive function (RBANS), delayed memory and visual reasoning showed sig training effect at 12 month FU – MDT better maintenance
Dahlin (2008)	Working memory training vs. control	RCT 5 weeks, 3x 45min session/ week FU: PT	EG: 11 CG: 10 Age: 65 – 71	Letter memory[a] Working memory[c]	No transfer to 3 back
Hastings (2009)	Evaluate self-help and group based training programmes. Group training vs. control	RCT 8 hours of training over 6weeks FU – PT and 9weeks	EG:98 CG:40 Age: 54 - 92	Face name recall[a] Story recall[a] List recall[c] Memory locus of control[a] Memory self-efficacy[a]	All maintained at 9 week follow-up. No measure of transfer included.
Fairchild (2010)	TEAM – training to enhance adult memory. In-home memory enhancement vs. control	RCT 1x 30mins-1hr session/ week for 6 weeks FU: PT	EG:28 CG:25 Age: 57 - 99	Face name recall[a] Delayed recall[a] Subjective CF[a]	[d]
Valentijn (2005)	Investigating two types of memory training. Collective training group vs. control	RCT Double baseline design 8 weeks FU – PT, 4 months	EG: 39 CG: 38 Age: >55	Immediate recall[c] Story recall[c] Delayed recall[a] MIA Change[a] MIA Anxiety[a] Memory self-efficacy[c] CFQ[c]	Intervention effects maintained to 4 month FU. No measure of transfer included.
Bailey (2010)	Meta-cognitive training	Standard intervention	EG = 29	Paired associates[a]	[d]

	at home vs. control	design 2 weeks training & 4 assignments FU: PT	CG = 27 Age: 60 – 89		
Ball (2002)	ACTIVE study: Cognitive training interventions. 4 conditions; memory training (MT), speed training (ST), reasoning training (RT) and control.	Single blind RCT 5 -6 weeks training FU: PT, annually at 1, 2, 3, and 5 years	MT:703, ST:702, RT:699, CG:698 Age: 65 – 94	MT: Memory[a] Reasoning[c] Speed of processing[c] IADL[c] ST: Memory[c] Reasoning[c] Speed of processing[a] IADL[c] RT: Memory[c] Reasoning[a] Speed of processing[c] IADL[a]	Each intervention improved target cognitive ability but no transfer to untrained cognitive tasks. Maintained at 5yr FU (Willis et al., 2006). Strategy use maintained at 5 yr FU (Gross & Reebok, 2011). Reasoning training transfer to sig less difficulties with IADL (Willis et al., 2006) at 5yr FU.[d]
Margrett (2006)	In home inductive reasoning training programme with couples. Partner training vs. control	RCT 10 sessions in 6 weeks FU: PT	EG:34 CG:34 Age: 61 - 89	Reasoning: Letter series[a] Word series[a] Letter sets[c]	

EG = experimental group; CG = control group; FU = Follow up; PT = Post training; MIA = Meta-Memory in Adulthood; CFQ = Cognitive Failures Questionnaire; Subjective CF = Subjective measures of cognitive function.
[a] Significantly greater improvement for training versus control.
[b] Significant training effects for experimental group from BL to PT; no significant effect for controls.
c No significant intervention difference between experimental and control groups.
d No measure of maintenance or transfer included.

Table 2
Characteristics of Studies - Cognitive Training vs. Active Control

Ref. Author (year)	Intervention	Methods	Participants	Outcomes of Interest	Generalisation/ Maintenance
Mahncke (2006)	Evaluating a brain-plasticity based training program EG: Computer based training AC: DVD based lectures, used similar equipment to EG	Double blind RCT 8-10 weeks of training (same for EG and AC) FU: PT and 3 months	EG: 53 AC: 53 Age: 60 – 87	Recognition[b] Speed of processing[b] Working memory[b] Global auditory memory (RBANS)[b]	Near transfer to untrained memory and WM tasks. Improvements on digit span maintained at 3 month FU for EG
Peretz (2011)	EG - personalized computerized cognitive training AC - conventional computer games	Double blind RCT. 20-30min/session, 3 sessions per week, 3 months. FU: PT	EG = 66 CG = 55 Age: >50	Recognition[c] Memory recall[c] Focused attention[a] Working memory[a] Visuospatial learning[a] Sustained attention[c] Executive function[c] Composite score[a]	Near transfer of training to untrained cognitive tasks
Smith (2009)	Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) study EG – Training to improve speed and accuracy of speed and information processing AC – DVD's on history, art and literature, quizzes.	Double blind RCT 40 sessions 1 hr. per day 5 days per week 8 weeks Re and post training assessment FU: PT; 3 months	EG =223 AG = 213 Age: >65	Overall memory[a] Immediate recall[c] Delayed recall[a] Reasoning[a] Working memory[a] Processing speed[a] Cognitive function[a] Subjective CF[a]	Far transfer to untrained domains of memory and attention. Significant training effects maintained at FU for memory measures and 3/5 measures of exec functioning. Not sig for cognitive function. Effects weaker at FU than PT.
Legault (2011)	SHARP-P cognitive and physical activity training (4 conditions) EG – Cognitive training intervention AC – A healthy aging education programme	Single-blind RCT 4x10-12 min sessions per day (2 per week for 2 months then 1 per week for 2 months) Duration over four months FU: PT	EG = 16 CG = 17 Age: 70-85	Immediate recall[c] Delayed recall[c] Working memory[c] Attention[c] Cognitive function[c]	No sig effects of CT or transfer to executive function tasks.

	(LIFE-P)				
Mozolic (2011)	Effects of a cognitive training intervention on attention. EG – Attention training AC – Educational lecture	RCT 8 weeks training 1 hour per week 8 hours total FU: PT	EG = 30 CG = 32 Age: 65-75	Immediate recall[c] Delayed recall[c] Selective attention[a] Processing speed[a] Attention (SCW, TMT)[c] Working memory[c]	Far transfer to non-trained domain of processing speed
Richmond (2011)	EG - Working Memory training with generalisation to untrained task AC –trivia learning	RCT Pre-test assessment, WM training: 4-5 weeks 5 days per week 20-30 min per day Total of 12.5 hrs FU: PT	EG = 21 CG = 19 Age: 60-80	Immediate recall[a] WM reading span[a] WM forward span[c] WM backward span[c] Attention[c] General intelligence[c] Subjective CF[a]	Far transfer of WM training effects to measures of verbal memory recall
Borella (2010)	EG – Working memory training AC – Questionnaires on memory, emotional competencies, personal satisfaction and coping strategies.	RCT A pre and post-test session with 3 training sessions in between, all within 2 weeks FU: PT, 8 months	EG = 20 CG = 20 Age: 65-75	Short term memory[c] Working memory[a] Attention[a] Processing speed[a] Fluid Intelligence[a] Visuospatial WM[c]	3 out of 4 transfer tasks (near and far) showed sig improvement for training compared to controls. Gains in intelligence and proc speed maintained at FU
Caretti (2012)	EG – Working memory training AC – Questionnaires on memory, cognition, well-being, memory strategies, Cattell test, etc	RCT Six sessions – training completed within 2 weeks, 30 – 40 minute sessions. FU: PT, 6 months.	EG = 17 CG = 19 Age: 65-75	Working memory[a] Attention[a] Language comprehension[a] Reading comprehension[b] Fluid Intelligence[b]	Near transfer to untrained tasks of WM. Far transfer to fluid intelligence and comprehension. Performance improvements for training group maintained from PT to FU
Nouchi (2012)	Effects of a brain training video game. EG – Game to train global cognitive & executive functions, attention and processing speed AC – A non-brain training video game	Double Blind RCT Both conditions played their game for 15 mins per day, at least five days per week, for 4 weeks FU: PT	EG = 14 CG = 14 Age: >65	Working memory[a] Executive function[a] Processing Speed[a] Attention[c] Cognitive function[c]	Near transfer of training to untrained measures of WM & processing speed. No transfer to global cognitive status or attention.
McDougall (2010)	The Senior WISE study. EG – Memory training AC – Health promotion training	RCT Memory Training: 8 classes and 4 booster sessions Health promotion training: 8 classes and 4 booster sessions FU: Post-class (2 months), post-booster (6 months), post-class follow-up (14 months), end of study (26 months)	EG = 135 CG =130 Age: >65	Verbal memory[c] Visual memory[c] Memory (RBMT)[c] Memory complaints[a] Memory self-efficacy[c] Cognitive function[a] Activities of daily living[c]	Near transfer to overall measure of cognitive function Improvements at PT were generally not maintained to the end of the study

EG = experimental group; CG = control group; FU = follow up; AC = active control; PT = post-test; BL = baseline; RBMT = Rivermead Behavioural Memory Test; WM = working memory; SCW = Stroop; TMT = Trail making test; Subjective CF = Subjective measures of cognitive function; DAFS = Direct Assessment of Functional Status.

[a] Significantly greater improvement for training versus control.

[b] Significant training effects for experimental group from BL to PT; no significant effect for controls.

[c] No significant intervention difference between experimental and control groups.

Table 3

Characteristics of Studies - General Mental Stimulation vs. No Intervention Control

Ref. Author (year)	Intervention	Methods	Participants	Outcomes of Interest	Generalisation/ Maintenance
Noice (2009)	Assessing the impact of acting classes on cognitive performance vs. control	RCT design 8x 1 hour sessions, 2 sessions/ week FU: PT	EG:42 CG:40 Age: >65	Immediate recall[a] Delayed recall[a] Verbal fluency[a] Problem solving[a] Working memory[c]	Training in acting classes showed transfer of effects to measures of memory, verbal fluency and problem solving
Klusmann (2010)	Computer course focused on complex cognitive tasks vs. control	RCT 3 x 1.5 hrs. per week for six months. 75 intervention units in total.	EG =81 CG = 69 Age: 70 - 93	Immediate recall[c] Delayed recall[a] Working memory[a] Verbal fluency[c]	Computer course showed transfer of effects to memory and executive function domain. EG

		FU: PT			maintained performance as opposed to CG who showed a decline.
Slegers (2009)	To assess if prolonged guided computer use affects cognition. Computer training & intervention vs. control (no training, no intervention)	RCT Training: 3x 4hr training sessions across 3wks Intervention: Once every 2 wks in 1st 4months, once every month for following 8 months. FU: PT, 12 months	EG: 60 CG: 52 Age: 64 – 75	Immediate recall[a] Attention[c] Delayed recall[c] Processing speed[c] Cognitive function[c] Subjective CF[c]	Computer training showed transfer of effects to memory domain. No overall significant intervention effects
Carlson (2008)	Experience Corps: Trained to help schoolchildren with reading, behaviour vs. control	RCT 15 hrs. per week for an academic year FU: PT	EG = 70 CG = 58 Age: >60	Immediate recall[c] Delayed recall[c] Executive function[a] Attention[a] Working memory[c] Processing speed[c]	Experience corps training showed transfer to tasks of executive function and attention
Basak (2008)	Video game training targeting executive control and visuospatial skills vs. control	RCT 7-8 weeks 15 1.5hr training sessions Total of 23.5hrs. FU: PT	EG = 19 CG = 20 Age: >65	Reasoning[a] Working memory[a] Attention[a] Visual STM[c] Visuospatial Attention[c]	Video game training showed transfer of effects to four out of five executive control tasks
Tesky (2011)	Cognitively stimulating leisure activities (AKTIVA) study. AKTIVA intervention vs. control	RCT 10 intervention sessions (8x wkly group training + 2x booster sessions) Completed 9x wkly activity protocols (wks 2-10) FU: PT	EG: 74 CG: 78 Age: >50 (divided into 60-75 & >75)	Processing speed[a] Working memory[c] Cognitive function[c] Subjective CF[c]	Transfer of training effects to processing speed task. No overall significant intervention effects
Bugos (2007)	Individual piano instruction targeting executive function and working memory vs. Control	RCT 30 min lesson with 3 hrs. of practise per week for total of 6 months FU: PT, 9 months	EG = 16 CG = 15 Age: 60-85	Processing speed[b] Attention[b] Working memory[c]	Transfer of training effects to processing speed and attention. No evidence of maintenance of performance gains for the experimental group at follow up.
Tranter (2008)	Effects of increased novel cognitively stimulating leisure activities vs. control	RCT 10-12 weeks FU: PT	EG: 22 CG: 22 Age 60 – 75	Cognitive function[a] Spatial perception[a]	Increased novel cognitive stimulation showed transfer to tasks of problem solving and flexible thinking

EG = experimental group; CG = control group; FU = follow up; AC = active control; PT = post-test; BL = baseline; STM = short term memory; Subjective CF = Subjective measures of cognitive function.
[a] Significantly greater improvement for training versus control.
[b] Significant training effects for experimental group from BL to PT; no significant effect for controls.
[c] No significant intervention difference between experimental and control groups.

Table 4
Characteristics of Studies - General Mental Stimulation vs. Active Control

Ref. Author (year)	Intervention	Methods	Participants	Outcomes of Interest	Generalisation/ Maintenance
Noice (2009)	Effects of acting classes on cognitive performance vs. singing classes	RCT design 8x 1 hour sessions, 2 sessions/ week FU: PT	EG:42 CG:40 Age: >65	Immediate recall[a] Delayed recall[a] Verbal fluency[a] Problem solving[a] Working memory[c]	Training in acting classes showed transfer of effects to measures of memory, verbal fluency and problem solving.
Klusmann (2010)	Computer course focused on complex cognitive tasks vs. physical exercise	RCT 3 x 1.5 hrs. per week for six months. 75 intervention units in total. FU: PT	EG: 81 CG: 80 Age: 70 - 93	Immediate recall[c] Delayed recall[c] Working memory[c] Verbal fluency[c]	No difference between EG and AC groups.
Slegers (2009)	Assessing if prolonged guided computer use affects cognition. Computer training & intervention vs. training with no intervention	RCT Training: 3x 4hr training sessions across 3wks Intervention: Once every 2 wks in 1st 4months, once every month for following 8 months. FU: PT, 12 months	EG: 60 CG: 47 Age: 64 – 75	Immediate recall[c] Delayed recall[c] Attention[c] Processing speed[c] Cognitive function[c] Subjective CF[c]	No overall significant intervention effects. Both groups performed significantly better on a measure of immediate recall compared to no intervention control.

EG = experimental group; CG = control group; FU = follow up; PT = post-test; BL = baseline; Subjective CF = Subjective measures of cognitive function.
[a] Significantly greater improvement for training versus control.
[c] No significant intervention difference between experimental and control groups.

Table 5

Characteristics of Studies - Group vs. Individual Training

Ref. Author (year)	Intervention	Methods	Participants	Outcomes of Interest	Generalisation/ Maintenance
Hastings (2009)	Evaluating group based vs. self-help training	RCT 8 hours of training over 6weeks FU – PT and 9weeks	EG:98 CG:45 Age: 54 - 92	Face name recall[c] List recall[c] Story recall[b] Memory self-efficacy[a] Locus of control[c]	All intervention effects maintained at 9 week follow-up.
Valentijn (2005)	Investigating two types of memory training. Collective training group vs. control	RCT Double baseline design 8 weeks FU – PT, 4 months	EG: 39 CG: 40 Age: >55	Delayed recall[a] Immediate recall[c] Story recall[c] MIA Anxiety[b] MIA Change[b] Memory self-efficacy[c] CFQ[c]	Excluding delayed recall, both groups showed similar improvements from baseline to PT. Intervention effects largely maintained to 4 month FU.
Margrett (2006)	In home inductive reasoning training programme with couples. Partner training vs. control	RCT 10 sessions in 6 weeks FU: PT	EG:34 CG:30 Age: 61 - 89	Reasoning: Letter series[c] Word series[c] Letter sets[c]	Both groups showed similar improvements from baseline to follow-up.

EG = experimental group; CG = control group; FU = follow up; PT = post-test; MIA = Meta-Memory in Adulthood; CFQ = Cognitive Failures Questionnaire.

[a] Significantly greater improvement for training versus control.

[b] Significant training effects for experimental group from BL to PT; no significant effect for controls.

[c] No significant intervention difference between experimental and control groups

Figure 1: Cognitive training versus no intervention control.

Figure 2: Cognitive training versus active control**.**

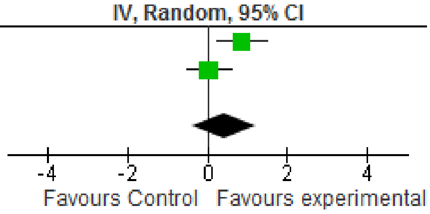
Figure 3: Training in group versus individual settings.

Figure 4. Number of studies per comparison–type included. CT = cognitive training; NI = no intervention; AC = active control; MS = mental stimulation; Grp = group–based intervention; Ind = individual intervention.

Figure 1

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Bottiroli 2009	7.14	5.54	21	1.83	6.57	23	48.8%	0.85 [0.23, 1.48]
Craik 2007	-0.42	2.35	29	-0.52	3.37	20	51.2%	0.04 [-0.53, 0.60]
Total (95% CI)			**50**			**43**	**100.0%**	**0.44 [-0.37, 1.24]**

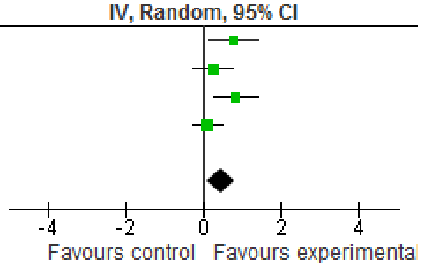
Heterogeneity: $Tau^2 = 0.24$; $Chi^2 = 3.64$, df = 1 (P = 0.06); $I^2 = 73\%$
Test for overall effect: Z = 1.06 (P = 0.29)



Outcome 1.1: Recognition

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Bottiroli 2009	4.19	4.3	21	1.17	3.36	23	20.5%	0.77 [0.16, 1.39]
Cavallini 2010	0.12	0.26	27	0.05	0.31	29	24.3%	0.24 [-0.29, 0.77]
Fairchild 2010	3.03	3.78	28	0.4	2.22	25	22.6%	0.82 [0.26, 1.39]
Hastings 2009	0.59	3.59	98	0.18	3.64	40	32.6%	0.11 [-0.25, 0.48]
Total (95% CI)			**174**			**117**	**100.0%**	**0.44 [0.07, 0.81]**

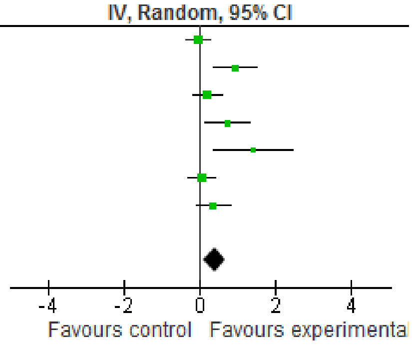
Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 6.25$, df = 3 (P = 0.10); $I^2 = 52\%$
Test for overall effect: Z = 2.35 (P = 0.02)



Outcome 1.2: Face Name Recall

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Buiza 2008	0.28	6.47	85	0.57	6.7	85	18.8%	-0.04 [-0.34, 0.26]
Cavallini 2010	0.18	0.17	27	0.03	0.15	29	13.0%	0.92 [0.37, 1.48]
Cheng (2012)	12.87	22.06	54	8.36	21.51	60	17.2%	0.21 [-0.16, 0.57]
Craik 2007	0.04	0.17	29	-0.09	0.18	20	12.3%	0.73 [0.15, 1.32]
Dahlin 2008	4.18	3.26	11	0.38	0.85	8	6.2%	1.42 [0.38, 2.46]
Hastings 2009	0.32	3.17	98	0.15	3.18	40	17.2%	0.05 [-0.31, 0.42]
Valentijn 2005	3.87	8.53	39	0.82	8.23	38	15.3%	0.36 [-0.09, 0.81]
Total (95% CI)			**343**			**280**	**100.0%**	**0.39 [0.09, 0.69]**

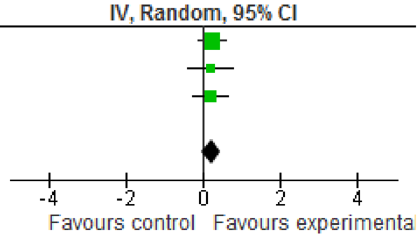
Heterogeneity: $Tau^2 = 0.10$; $Chi^2 = 18.18$, df = 6 (P = 0.006); $I^2 = 67\%$
Test for overall effect: Z = 2.52 (P = 0.01)



Outcome 1.3: Immediate Recall

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Cheng (2012)	13.27	24.85	54	7.34	24.55	60	47.7%	0.24 [-0.13, 0.61]
Craik 2007	0.36	2.43	29	-0.12	2.86	20	19.9%	0.18 [-0.39, 0.75]
Valentijn 2005	0.63	5.1	39	-0.47	6.05	38	32.4%	0.19 [-0.25, 0.64]
Total (95% CI)			**122**			**118**	**100.0%**	**0.21 [-0.04, 0.47]**

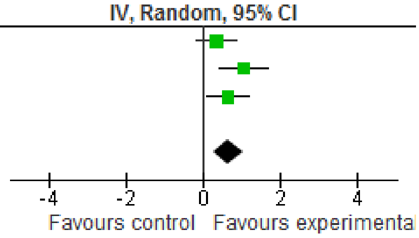
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.04$, df = 2 (P = 0.98); $I^2 = 0\%$
Test for overall effect: Z = 1.64 (P = 0.10)



Outcome 1.4: Delayed Recall

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Bailey 2010	5.72	12.86	29	1.56	11.71	27	36.4%	0.33 [-0.20, 0.86]
Bottiroli 2009	3.29	3.07	21	-0.16	3.35	23	28.2%	1.05 [0.42, 1.69]
Cavallini 2010	0.09	0.16	27	-0.0078	0.14	29	35.5%	0.64 [0.10, 1.18]
Total (95% CI)			**77**			**79**	**100.0%**	**0.65 [0.25, 1.04]**

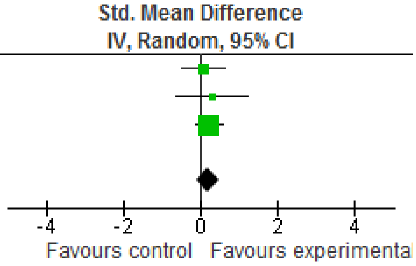
Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 2.92$, df = 2 (P = 0.23); $I^2 = 31\%$
Test for overall effect: Z = 3.22 (P = 0.001)



Outcome: 1.5 Paired Associates

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Craik 2007	0.28	1.39	29	0.1	2.83	20	27.5%	0.08 [-0.49, 0.65]
Dahlin 2008	5.37	10.39	11	2.25	9.24	8	10.6%	0.30 [-0.62, 1.22]
Mahncke 2006	0.7	2.18	53	0.2	2.24	54	61.8%	0.22 [-0.16, 0.60]
Total (95% CI)			**93**			**82**	**100.0%**	**0.19 [-0.10, 0.49]**

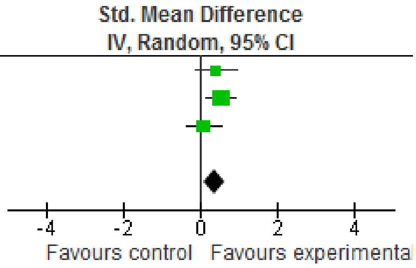
Heterogeneity: Tau² = 0.00; Chi² = 0.22, df = 2 (P = 0.90); I² = 0%
Test for overall effect: Z = 1.27 (P = 0.20)



Outcome 1.6: Working Memory

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Fairchild 2010	7.71	14.31	28	0.88	18.64	25	23.0%	0.41 [-0.14, 0.95]
Hastings 2009	6.65	19.9	98	-3.954	19.77	40	44.3%	0.53 [0.16, 0.90]
Valentijn 2005	0.987	17.38	39	-0.455	16.99	38	32.7%	0.08 [-0.36, 0.53]
Total (95% CI)			**165**			**103**	**100.0%**	**0.36 [0.08, 0.63]**

Heterogeneity: Tau² = 0.01; Chi² = 2.31, df = 2 (P = 0.31); I² = 13%
Test for overall effect: Z = 2.54 (P = 0.01)

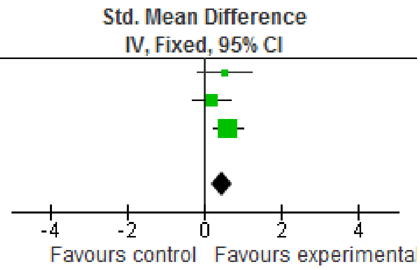


Outcome 1.7: Subjective Memory

Figure 2

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Legault 2011	0.42	1.98	16	-0.59	1.73	17	15.3%	0.53 [-0.17, 1.23]
Mozolic 2011	0.8	3.19	30	0.2	2.94	32	29.6%	0.19 [-0.31, 0.69]
Peretz 2011	3.06	0.92	66	2.47	1.01	55	55.1%	0.61 [0.24, 0.98]
Total (95% CI)			**112**			**104**	**100.0%**	**0.47 [0.20, 0.75]**

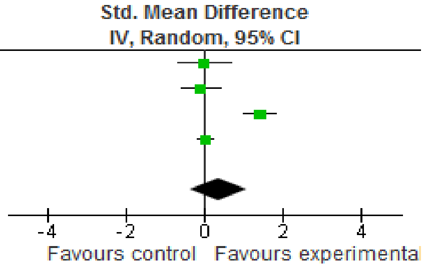
Heterogeneity: Chi² = 1.76, df = 2 (P = 0.41); I² = 0%
Test for overall effect: Z = 3.42 (P = 0.0006)



Outcome 2.1: Recognition

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Legault 2011	3	4.15	16	3.1	6.95	17	22.4%	-0.02 [-0.70, 0.67]
Mozolic 2011	0.8	2.13	30	1	2.2	32	24.6%	-0.09 [-0.59, 0.41]
Peretz 2011	3.65	1.05	66	2.09	1.15	55	25.7%	1.41 [1.01, 1.81]
Smith 2009	0.6	3.81	223	0.5	3.72	213	27.3%	0.03 [-0.16, 0.21]
Total (95% CI)			**335**			**317**	**100.0%**	**0.34 [-0.38, 1.07]**

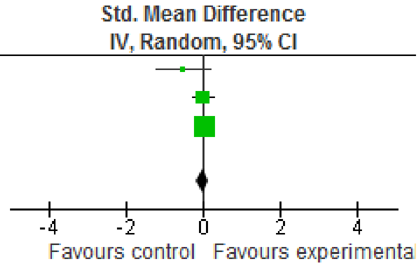
Heterogeneity: Tau² = 0.49; Chi² = 40.07, df = 3 (P < 0.00001); I² = 93%
Test for overall effect: Z = 0.93 (P = 0.35)



Outcome 2.2: Immediate Recall

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Legault 2011	1.69	4.76	16	4.65	5.95	17	6.1%	-0.53 [-1.23, 0.16]
McDougall 2010	0.67	15.01	107	0.78	16.44	99	33.9%	-0.01 [-0.28, 0.27]
Smith 2009	0.7	3.81	223	0.6	2.98	213	59.9%	0.03 [-0.16, 0.22]
Total (95% CI)			**346**			**329**	**100.0%**	**-0.02 [-0.19, 0.16]**

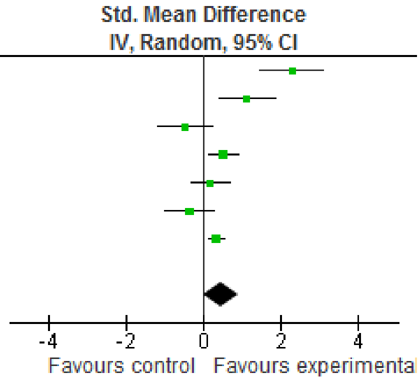
Heterogeneity: Tau² = 0.00; Chi² = 2.34, df = 2 (P = 0.31); I² = 15%
Test for overall effect: Z = 0.20 (P = 0.84)



Outcome 2.3: Delayed Recall

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Borella 2010	2.3	1.13	20	-0.45	1.23	20	11.6%	2.28 [1.47, 3.10]
Caretti 2012	4.25	3.75	17	0.65	2.43	19	12.7%	1.13 [0.42, 1.84]
Legault 2011	0.02	0.24	16	0.13	0.21	17	12.9%	-0.48 [-1.17, 0.22]
Mahncke 2006 CTvAC	0.7	2.18	53	-0.4	2.18	53	16.3%	0.50 [0.11, 0.89]
Mozolic 2011	0.4	1.14	30	0.2	1.06	32	15.1%	0.18 [-0.32, 0.68]
Richmond 2011	-0.24	2.92	21	0.84	3.12	19	13.6%	-0.35 [-0.98, 0.27]
Smith 2009	0.6	1.52	223	0.1	1.49	213	17.9%	0.33 [0.14, 0.52]
Total (95% CI)			**380**			**373**	**100.0%**	**0.47 [0.01, 0.92]**

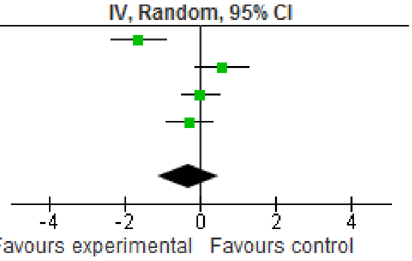
Heterogeneity: Tau² = 0.29; Chi² = 37.58, df = 6 (P < 0.00001); I² = 84%
Test for overall effect: Z = 2.02 (P = 0.04)



Outcome 2.4: Cognitive Training vs. Active Control: Working Memory.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Borella 2010	-8.7	4.46	20	-1.25	4.5	20	23.9%	-1.63 [-2.35, -0.90]
Legault 2011	-1.94	30.62	16	-23.3	40.42	17	24.3%	0.58 [-0.12, 1.28]
Mozolic 2011	-7.3	41.04	30	-6.4	44.27	32	26.6%	-0.02 [-0.52, 0.48]
Richmond 2011	-0.33	6.16	21	1.47	6.15	19	25.2%	-0.29 [-0.91, 0.34]
Total (95% CI)			**87**			**88**	**100.0%**	**-0.33 [-1.14, 0.49]**

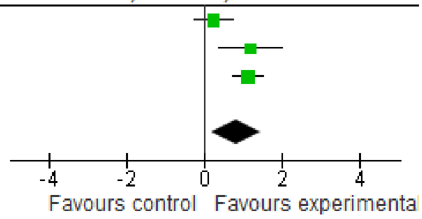
Heterogeneity: $Tau^2 = 0.58$; $Chi^2 = 20.14$, df = 3 (P = 0.0002); $I^2 = 85\%$
Test for overall effect: Z = 0.79 (P = 0.43)



Outcome 2.5: Attention

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Mozolic 2011	0.4	1.2	30	0.1	1.27	32	35.3%	0.24 [-0.26, 0.74]
Nouchi 2012	8.29	7.03	14	-0.98	8.08	14	25.8%	1.19 [0.38, 2.00]
Peretz 2011	5.03	1.53	66	3.25	1.68	55	38.9%	1.11 [0.72, 1.49]
Total (95% CI)			**110**			**101**	**100.0%**	**0.82 [0.19, 1.45]**

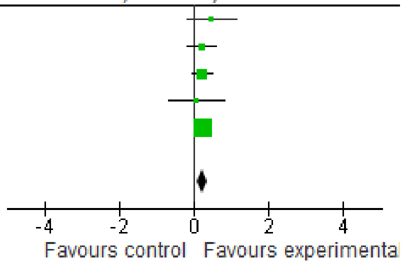
Heterogeneity: $Tau^2 = 0.22$; $Chi^2 = 8.07$, df = 2 (P = 0.02); $I^2 = 75\%$
Test for overall effect: Z = 2.57 (P = 0.01)



Outcome 2.6: Processing Speed

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Caretti 2012	3.75	4.16	17	1.05	6.68	19	4.3%	0.47 [-0.20, 1.13]
Mahncke 2006 CTvAC	2.3	6.55	53	1	6.55	53	13.1%	0.20 [-0.18, 0.58]
McDougall 2010	0.26	2.75	106	-0.21	1.33	97	25.1%	0.21 [-0.06, 0.49]
Nouchi 2012	0.36	1.28	14	0.29	1.33	14	3.5%	0.05 [-0.69, 0.79]
Smith 2009	3.9	9.14	223	1.8	8.93	213	53.9%	0.23 [0.04, 0.42]
Total (95% CI)			**413**			**396**	**100.0%**	**0.23 [0.09, 0.37]**

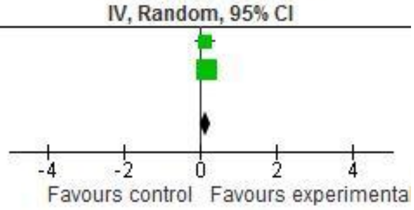
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.76$, df = 4 (P = 0.94); $I^2 = 0\%$
Test for overall effect: Z = 3.21 (P = 0.001)



Outcome 2.7: Cognitive Function

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
McDougall 2010	2.16	26.24	135	-0.67	23.45	130	37.8%	0.11 [-0.13, 0.35]
Smith 2009	0.069	0.29	223	0.025	0.29	213	62.2%	0.15 [-0.04, 0.34]
Total (95% CI)			**358**			**343**	**100.0%**	**0.14 [-0.01, 0.29]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.06$, df = 1 (P = 0.81); $I^2 = 0\%$
Test for overall effect: Z = 1.81 (P = 0.07)

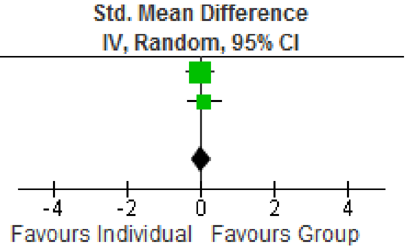


Outcome 2.8: Subjective Memory

Figure 3

	Experimental			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Hastings 2009 Gvl	0.32	3.17	98	0.4	3.13	45	61.0%	-0.03 [-0.38, 0.33]
Valentijn 2005 Gvl	3.87	12.06	39	2.6	13.57	40	39.0%	0.10 [-0.34, 0.54]
Total (95% CI)			**137**			**85**	**100.0%**	**0.02 [-0.25, 0.30]**

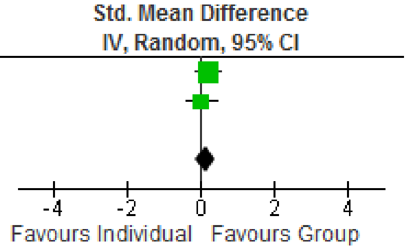
Heterogeneity: Tau² = 0.00; Chi² = 0.18, df = 1 (P = 0.67); I² = 0%
Test for overall effect: Z = 0.16 (P = 0.87)



Outcome 5.1: Immediate Recall

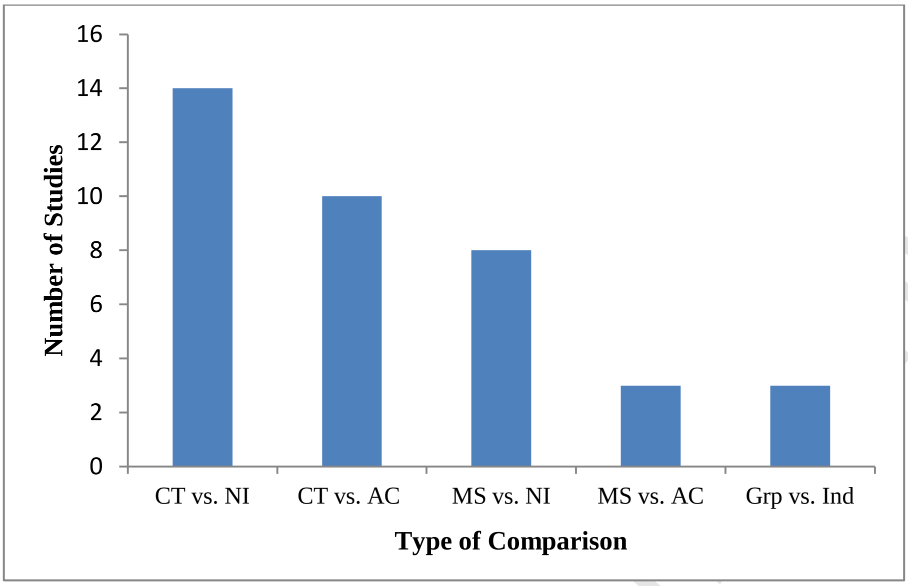
	Experimental			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Hastings 2009 Gvl	6.65	19.9	98	2.35	20.01	45	60.8%	0.21 [-0.14, 0.57]
Valentijn 2005 Gvl	0.987	17.38	39	0.698	17.28	40	39.2%	0.02 [-0.42, 0.46]
Total (95% CI)			**137**			**85**	**100.0%**	**0.14 [-0.14, 0.41]**

Heterogeneity: Tau² = 0.00; Chi² = 0.47, df = 1 (P = 0.49); I² = 0%
Test for overall effect: Z = 0.97 (P = 0.33)



Outcome 5.2: Subjective Memory

Figure 4


16
14
12
10
8
6
4
2
0
Number of Studies
CT vs. NI
CT vs. AC
MS vs. NI
MS vs. AC
Grp vs. Ind
Type of Comparison

Highlights

- Cognitive training can improve older adults' performance on cognitive tasks
- Interventions comprising general mental stimulation may benefit cognitive function but further research is required
- Effects of cognitive training can transfer to untrained tasks, untrained domains, and everyday functioning
- The effects of cognitive training can be maintained for up to six months
- Group cognitive training may have subjective and cognitive benefits over training in individual settings