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Memory training interventions for older adults: A meta-analysis

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Abstract

A systematic review and meta-analysis of memory training research was conducted to characterize the effect of memory strategies on memory performance among cognitively intact, community-dwelling older adults, and to identify characteristics of individuals and of programs associated with improved memory. The review identified 402 publications, of which 35 studies met criteria for inclusion. The overall effect size estimate, representing the mean standardized difference in pre-post change between memory-trained and control groups, was 0.31 standard deviations (SD; 95% confidence interval (CI): 0.22, 0.39). The pre-post training effect for memory-trained interventions was 0.43 SD (95% CI: 0.29, 0.57) and the practice effect for control groups was 0.06 SD (95% CI: -0.05, 0.16). Among 10 distinct memory strategies identified in studies, meta-analytic methods revealed that training multiple strategies was associated with larger training gains (p=0.04), although this association did not reach statistical significance after adjusting for multiple comparisons. Treatment gains among memory-trained individuals were not better after training in any particular strategy, or by the average age of participants, session length, or type of control condition. These findings can inform the design of future memory training programs for older adults.

Keywords

memory training; memory; strategy use; meta-analysis; mnemonics

Introduction

Training programs designed to enhance memory among older adults have proliferated in recent years. Memory training programs exist within the larger context of cognitive training, which is based on the notion that cognition is plastic in older age (Acevedo & Lowenstein, 2007; Rebok, Carlson, & Langbaum, 2007). Through cognitive plasticity and reserve (Stern, 2002), mentally stimulating activities like memory training help maintain and improve cognitive and functional abilities in daily life (Hertzog et al., 2008). Memory training interventions facilitate plasticity by teaching various strategies that help encode and retrieve information (Gross & Rebok, 2011; McDaniel, Einstein, & Jacoby, 2008; Rebok et al.,

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2007; Verhaeghen, Marcoen, & Goossens, 1992). In addition to improving objective memory performance, research shows interventions can improve self-rated subjective memory (Floyd & Scogin, 1997).

Memory training interventions among older adults with no cognitive impairment seek to improve memory skills by teaching mnemonic techniques. Common mnemonic strategies include rehearsal (Gordon & Berger, 2003; Heun, Burkart, & Benkert, 1997; Howe et al., 1985; Kennedy & Miller, 1976), association (Bjorklund & Douglas, 1997; West, 1985), categorization (Bjorklund, Schneider, Cassel, & Ashley, 1994; Gobet, Lane, Croker, Cheng, Jones, et al., 2001; Ornstein & Naus, 1978; Schneider & Sodian, 1988), imagery (Bower, 1970; Poon et al., 1980; Rankin, Karol, & Tuten, 1984; Rasmusson et al., 1999; Richardson, 1998; Sharps & Price-Sharps, 1996), and concentration (Stigsdotter & Bäckman, 1989). Combinations of these strategies are often taught in memory training programs and include face-name recognition and name-face learning, number mnemonics, story mnemonics, and the method of loci. Additionally, training programs often entail instruction in how to take advantage of environmental supports, called external memory aids.

Evidence from several studies suggests training may help maintain, or potentially enhance, memory performance in later adulthood. Specifically, the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study, the largest randomized trial of cognitive training among older adults to date, reported a retest-adjusted effect size of 0.26 standard deviations (SD) comparing memory gains immediately after memory training with change in the no-contact control group, and an effect size of 0.23 SD five years after training (Willis et al., 2006). The potential for improvement in memory is mirrored by findings from systematic reviews and meta-analyses of memory training. Verhaeghen and colleagues (1992) reported an average standardized pre-post training gain of 0.73 SD in memory performance from training, indicating memory training can improve memory in cognitively normal older adults. Additionally, Verhaeghen et al. (1992) reported that mnemonic strategies that capitalized on imagery were most effective for increasing memory performance. Many studies have been conducted in the decades since the review by Verhaeghen and colleagues was published, and the topic of effective memory training strategies is worth revisiting. Further, their estimate did not adjust for practice, or retest, effects, which were 0.37 SD for placebo or active control groups and 0.36 SD for no-contact control groups (Verhaeghen et al., 1992). Retest effects are artifacts of prior test experience rather than of processes of interest to a research question (Salthouse & Tucker-Drob, 2008; Salthouse, 2010). They are attributable to changes in attention and increased expectancy that arise with repeated test administrations, and are important to account for in studies with repeated measures because prior exposure to test materials provides knowledge and test-taking experience that confound true training-related performance gains (Crawford et al., 1989; Mitrushina et al., 2005). More recently, a meta-analysis by Zehnder and colleagues (2009; Martin, Clare, Altgassen, Cameron, & Zehnder, 2011) studied the effect of memory training on particular memory abilities, and reported training effects for paired associate learning, immediate recall, and delayed recall.

Memory training for older adults has proliferated in recent years, often without rigorous empirical testing. Researchers and commercial businesses (e.g., Burden, 1988) have developed memory training programs that target particular populations of older adults, including those with no cognitive impairment (e.g., Willis et al., 2006), mild cognitive impairment or memory complaints (e.g., Craik et al., 2007), and dementia (Cherry & Simmons-D'Gerolamo, 2005; Zanetti et al., 1997). Programs for cognitively normal older adults, the focus of the present article, typically entail interactive group sessions over several days or weeks with a trainer (e.g., Zarit, Cole, & Guider, 1981), but also include self-guided training with take-home packets (e.g., Burden, 1988; Scogin et al., 1985).

Research on the impact of participant and program characteristics on memory training effectiveness is widespread but has produced conflicting results. Existing evidence suggests older age is associated with less training benefit (Verhaeghen et al., 1992; Yesavage, Sheikh, Friedman, & Tanke, 1990), though not all studies replicate this finding (e.g., Rasmusson et al., 1999; Schmidt et al., 2001; Singer, Lindenberger, & Baltes, 2003; Wolters, Theunissen, Bemelmans, van der Does, & Spinhoven, 1996). Effects of adherence and training length are understudied in memory training research. Although prior studies have demonstrated memory gain following mnemonic instruction over only one or two sessions (e.g., Rebok & Balcerak, 1989), group-based memory training programs typically last between five and fifteen hour-long sessions (Mahncke et al., 2006; Rebok et al., 2007).

Altogether, prior studies of memory training in later life have reported training interventions benefit older adults' memory. Existing studies, however, seldom have evaluated training effects by the type of mnemonic strategy employed. The present systematic review and meta-analysis summarizes nearly 50 years of memory training research to address the following questions: (1) What is the average overall pre-to-post difference in effect between memory-trained and control groups? (2) Are particular mnemonic or other strategies taught during training more effective than others in improving memory? and (3) Are participant or program characteristics, such as participant age or intervention duration, associated with greater intervention effectiveness among community-dwelling older adults?

Methods

A comprehensive review was conducted of research on memory training interventions for cognitively normal older adults published or in press prior to January, 2010. To identify relevant studies, computerized databases (PsychInfo, PsychLit, PubMed) were searched using combinations of the following key words: *memory, mnemonic, cognitive, cognition, intervention, training, rehabilitation, stimulation, learning, improvement, enhancement, older adult, aging, elderly*, and *impairment*. We searched published reviews and meta-analyses (e.g., De Vreese et al., 2001; Floyd & Scogin, 1997; Grandmaison & Simard, 2003; Sitzer et al., 2006; Storandt, 1991; Verhaeghen et al., 1992); and performed hand searches of journals (e.g., *Applied Cognitive Psychology; Educational Gerontology; Cognitive Technology; Psychology and Aging*), and book chapters (e.g., Hill, Bäckman, & Stigsdotter-Neely, 2000). Authors of memory training studies were contacted for recently published or in press studies. Additional studies were identified from reference lists in retrieved articles.

Inclusion criteria for this meta-analysis were based on criteria for identification of evidence-based treatments developed for the Committee on Science and Practice, Society for Clinical Psychology, and Division 12 of the American Psychological Association. Detailed procedures for identifying, reviewing, and coding studies of psychological interventions are described in detail by Weisz and Hawley (2001). To be included in the present review, publications were required to report original data on memory training. All participants had to be at least 60 years of age at the time of training. This criterion was necessary because a treatment in a different age group is considered a new application of the treatment and may have different effects (Chambless & Hollon, 1998). Studies must have used a non-pharmacological approach targeted at memory or memory problems (Weisz & Hawley, 2011), and had to be published in English.

Theoretical articles, review articles, and book chapters that did not include original data were excluded. Studies were also excluded if the study design tested effects of a combination of memory training and pharmacotherapy or exercise therapy because we did not want to confound effects of memory training with pharmacologic effects. If the treatment program only involved practice with memory tasks or instruction manipulation but no training (e.g., psychological experiments on memory), we excluded the study. If there was no comparable control group (block randomization or comparable control groups were accepted in lieu of full randomization), we were unable to disambiguate treatment effects from baseline differences. Further, only outcome measures of objective memory performance were collected from eligible studies; outcome measures of other cognitive domains (e.g., executive functioning, attention), global cognitive status, and everyday function were excluded.

Strategy ascertainment

Initially, 402 articles published between 1967 and 2010 were deemed relevant to the present review. Not all these studies were appropriate for our review. Two independent reviewers reviewed each study and extracted information about the study design, sample age, memory outcomes, and means and standard deviations of memory tests before and after training in trained and control groups. Percent agreement among reviewers was high (95%), suggesting excellent inter-rater reliability. All differences were resolved by consensus. Raters also coded specific memory strategies taught as part of the training program. Mnemonic strategies were classified into rehearsal, associations, categorization, imagery, concentration, face–name recognition, number mnemonics, story mnemonics, method of loci, and external memory aids. In several cases, authors were contacted for their training manuals (e.g., Dunlosky et al., 2003; Scogin et al., 1985). These categories were determined post hoc after a thorough review of each eligible study. Mnemonic strategy classifications are described below.

Rehearsal entails repetition of information to facilitate encoding (Gordon & Berger, 2003; Heun, Burkart, & Benkert, 1997; Howe et al., 1985; Kennedy & Miller, 1976). *Associations* are links or connections formed between items with respect to time, environment, or specific item characteristics, and made using images, senses, words, and sentences (Bjorklund & Douglas, 1997; West, 1985). *Categorization* involves recognizing and grouping items by conceptual relations to facilitate remembering (Bjorklund et al., 1994; Gobet et al., 2001; Ornstein & Naus, 1978; Schneider & Sodian, 1988). *Imagery* entails binding together concepts or items into an integrated, often visual, representation (Bower, 1970; Poon et al., 1980; Rankin, Karol, & Tuten, 1984; Rasmusson et al., 1999; Richardson, 1998; Sharps & Price-Sharps, 1996). Visual imagery is useful for list-learning, prospective memory, and other types of memory. Training in *concentration* involves enhancing listening and information processing skills using divided attention and selective processing tasks (Stigsdotter & Bäckman, 1989).

Combinations of rehearsal, association, categorization, imagery, and concentration are often taught in memory training programs as stand-alone strategies helpful in particular contexts. These strategies include *face–name recognition* and *name–learning techniques, number mnemonics*, and *story mnemonics. Face–name recognition* is used to remember names and faces together by integrating mnemonic devices like visual imagery, categorization, and association to link a person's name with his or her facial characteristics (Andrewes et al., 1996; Becker, McDougall, Douglas, & Arheart, 2008; Best et al., 1992; Calero & Navarro, 2007; Calero–Garcia & Navarro–Gonzalez, 2007; Craik et al., 2007; Dunlosky et al., 2003; Fabre et al., 2002; Lachman et al., 1992; Lustig, 2008; Mohs et al., 1998; Stigsdotter et al., 1989; Woolverton et al., 2001). *Number mnemonics*, also referred to as the phonetic system, digit–consonant method, and the major system (Worthen & Hunt, 2011), are used to remember strings of numbers like dates, phone numbers, and addresses (Calero & Navarro, 2007; Calero–Garcia & Navarro–Gonzalez, 2007; Derwinger et al., 2005; Hill et al., 1997). Use of this strategy entails creating a codebook to substitute letters for numbers by associating all numbers with characters or phonemes, generation of words and phrases using letters that correspond with to-be-remembered numbers, and finally, translating the word or phrase back into the original numbers using the codebook. *Story and sentence mnemonics* involve creating a story or sentence with to–be–remembered items to facilitate recall (e.g., Hill et al., 1991). This type of strategy relies on the distillation of thoughts or items into representative words or phrases (Small, 2002).

The *method of loci* is a formal visuo-spatial mnemonic device that takes advantage of known places, such as body parts or landmarks on the way to work, and pairs each location with a to-be-remembered item (Bower, 1970; Yates, 1966). This structured sequence of images provides memory cues to facilitate recall (Hill et al., 1991; Kliegl, Smith, & Baltes, 1989, 1990; Rebok & Balcerak, 1989; Verhaeghen & Marcoen, 1996; Yesavage & Rose, 1984).

External memory aids are environmental cues that enhance memory and everyday functioning (Andrewes et al., 1996; Best et al., 1992; Caprio-Prevette et al., 1996; Craik et al., 2007; Flynn et al., 1990; Hanley & Lusty, 1984; McPherson et al., 2001; Nolan et al., 2001; Scogin et al., 1985; Scogin et al., 1992; Scogin et al., 1998; Woods et al., 2006; Woolverton et al., 2001; Worthen & Hunt, 2011). External memory aids include lists, reminder notes, calendars, and messages to one's self.

Effect size calculation

To characterize the immediate effect of memory training on memory among older adults, effect sizes were calculated in two ways. First, average pre-post effect sizes were calculated for memory-trained and control groups separately. Most studies reported multiple measures of memory ability, and we took an arithmetic mean of the effect sizes for these measures. Common memory tasks used to measure memory included verbal word list-learning tasks (Auditory Verbal Learning Test (Rey, 1964), California Verbal Learning Test (Delis et al., 1987), Hopkins Verbal Learning Test (Brandt & Benedict, 2001)), paragraph recall (e.g., Rivermead Behavioral Memory test (Wilson, Cockburn, & Baddeley, 1985)), and assorted tests of recall for numbers, images, and shopping lists. For each memory outcome provided by a study, the mean difference between the post-training and pre-training scores for the trained group was divided by the pooled standard deviation to place all effect sizes on the same scale. The same was done for the control group. These effect sizes are within-study averages of all reported memory measures that represent a study-specific training effect and a control retest effect. We used these study-specific composites of memory performance because the present study's goal was to make statements about the construct of memory and not to distinguish types of memory. An advantage of using composites is they are likely less similar to tasks on which participants were trained than some specific memory tests used by a study to measure training effects. We did not distinguish memory measures by primary or secondary outcomes as identified by each individual study. Pre-training and post-training means and standard deviations were available from almost all studies; standard deviations were determined from inferential statistics (e.g., F statistics, t statistics, confidence intervals on barcharts) in five cases (Andrewes et al., 1994; Best et al., 1992; Caprio-Prevette & Fry, 1996; Yesavage, 1983, 1984). In these five cases, pre-post effect sizes were calculated using inflated standard deviation estimates to account for correlation between the two measures (Dunlap, Cortina, Vaslow, & Burke, 1996).

Retest-adjusted effect sizes were also calculated by taking a difference in pre-post change between memory and control groups for each memory measure in a study, and standardized using a pooled standard deviation. Unlike the first set of effect sizes, which were standardized differences in memory change between baseline and immediate post-training assessments and provided largely for descriptive purposes, retest-adjusted effect sizes represent memory change attributable to training by adjusting for a retest effect in control groups. The latter set of effect sizes was used for the meta-analysis in the present study. This analysis assumed that retest effects are comparable between trained and control participants.

Statistical analysis

Meta-analytic procedures were used to analyze retest-adjusted effect sizes from the systematic review. Study-specific effect size estimates were weighted by the study sample size and combined to form an overall effect size. Forest plots were constructed to display study-specific effect sizes. Funnel plots were used to visually inspect evidence of publication bias. Between-study heterogeneity was quantified using χ^2 and I^2 statistics, the latter of which is interpreted as the chance-adjusted percent of total variation attributable to between-study heterogeneity. Sources of heterogeneity were explored using separate random effects meta-regressions of effect size estimates on covariates. Because of the small sample size, separate meta-regressions were performed for each of the 15 predictors. A two-sided α-level <0.05 was used as a cutoff for statistical significance, although results from meta-regressions were adjusted for multiple comparisons using a Bonferroni adjustment (Bonferroni, 1935). All analyses were performed using the Stata version 11.0 software package (StataCorp, 2010).

Results

Based on the stated inclusion and exclusion criteria, 33 of the 402 publications were memory training studies involving randomization to memory training for older adults and therefore eligible for inclusion in the present review. Common reasons for exclusion involved designs that mixed memory training with a pharmacological, physical, or social engagement intervention (e.g., Rozzini et al., 2007; Tárraga et al., 2006); samples with individuals under 60 years of age (e.g., Bherer et al., 2006; Erickson et al., 2007; Hildebrandt et al., 2006; McKitrick, Camp, & Black, 1992; Troyer et al., 2008); studies without comparable control groups (e.g., Morrell, 2006); or theoretical or review articles (e.g., Acevedo & Loewenstein, 2007; Belleville, 2008; Clare & Woods, 2004; Dunlosky et al., 2007; McDougall, 2004).

The 33 publications provided 35 separate treatment-control studies because two studies included multiple treatment conditions alongside a control condition (Derwinger et al., 2005; Woolverton et al., 2001). From these, nine different mnemonic strategies and external memory aids used in memory training were identified with a total participant sample of 3,797 (Table 1). The mean sample age among included studies was 72.7 years (SD = 4.3; range of actual ages = 60 to 98 years). Most participants assigned to training completed the training according to study criteria (e.g., attended a certain number of sessions) or at least provided data at post-training. Training programs lasted anywhere in total duration from 30 minutes to 24 hours; most were administered in between one and 20 sessions. The majority of memory interventions were conducted in a group format. All studies followed an established, consistent protocol (Table 1).

Among strategies taught for improving memory, visual imagery was the most prevalent, followed by face-name and name-learning techniques (Table 1). Only 29% of programs trained on a single strategy. The majority of memory training programs taught between two and seven different strategies. The most common combination of strategies was at least three of the following: method of loci, association, categorization, and visual imagery (Ball et al., 2002; Becker et al., 2008; Best, Hamlett, & Davis, 1992; Calero & Navarro, 2007; Calero-Garcia & Navarro-Gonzalez, 2007; McDougall et al., 2010; Scogin & Prohaska, 1992).

Effect sizes with 95% confidence intervals for each study in the present review are shown with a Forest plot (Figure 1). The overall pre-post training gain was 0.43 SD (95% CI: 0.29, 0.57) and the mean retest effect among control groups was 0.06 SD (95% CI: -0.06, 0.16; Table 2). Figure 2 reveals bell-shaped distributions of training and control effect sizes and a broader range of training effects than retest effects. The latter observation is consistent with tests of heterogeneity in Table 2. The mean standardized difference in pre-post change between memory and control groups was 0.31 SD (95% CI: 0.22, 0.39), indicating that, on average, memory-trained participants demonstrated a 0.31 SD greater improvement in memory performance than participants in the control condition. This difference was statistically significant ($p < 0.001$). A funnel plot of these effect sizes shows minimal asymmetry and thus no evidence of publication bias, although two studies (Best et al., 1992; Hill et al., 1990) provided very large effect sizes (Figure 3).

Statistical tests for heterogeneity in Table 3 (χ^2 and I^2) suggested negligible between-study heterogeneity in pre-post differences between training and control groups (Table 2), but for theoretical reasons and because pre-post changes in memory among memory-trained groups were heterogeneous, we further regressed effect sizes on several predictors in separate meta-regressions (Table 3). No individual or study characteristics (age, hours trained, percentage of completers, placebo versus no-contact control group) were associated with greater pre-post gains in memory-trained groups (Table 3). Although categorization and repetition mnemonic strategies were statistically significant at the α=0.05 level, they were not significant at the Bonferroni-adjusted α=0.003 level. We regressed effect sizes on the number of strategies. Similar to findings for individual strategies, the total number of strategies was also positively associated with an increased standardized pre-post difference between memory and control groups but was no longer significant after the Bonferroni correction (Table 3).

Discussion

The present study reports results from a meta-analysis of nearly 50 years of memory training studies. Consistent with the view that memory can be improved in older adulthood, memory gains in training groups were larger than retest effects in control groups. The standardized difference in pre-post gain between memory and control groups was 0.31 SD, which is comparable to the difference between effect of training and the retest effect for control groups in the review by Verhaeghen and colleagues (1992) and is larger than in ACTIVE. Meta-regressions further revealed that providing training on more strategies was moderately associated with larger memory improvement. No other mnemonic strategies or study characteristics were significantly associated with memory improvement.

A challenge of memory training studies, like most cognitive training interventions, is that they often do not train abilities that generalize to everyday functioning (Hertzog et al., 2008). This is why an intervention’s scope, or the breadth of strategies trained, is important to characterize in any study. Individual strategies and the total number of strategies taught served as indicators of intervention scope in this study. Interventions that train more or broader techniques have a better chance than interventions that target fewer abilities of teaching something that resonates with an older adult, which they then might use to ameliorate their everyday lives (Hertzog et al., 2008). The trend for more improvement after training with more strategies trained, though not significant after adjustment for multiple comparisons, is consistent with the notion that studies with more variety of strategies have a larger scope and more chance of teaching strategies that older adults may internalize. This reasoning leads to the hypothesis that memory training interventions that train more strategies should yield more robust effects in everyday life; however, future research is needed to explore this possibility.

Suggestive but nonsignificant trends for larger effect sizes for rehearsal and categorization are worth mention. Because rehearsal was trained in only three of the 35 studies and never the only strategy trained, this finding is consistent with the notion that rehearsal in combination with other strategies can explain between-study variability. Although Ebbinghaus' (1895/1964) seminal work on memory entailed memorizing nonsense syllables using only rote repetition, contemporary research indicates that rehearsal alone does not improve memory, but that it does provide an opportunity to form associations to facilitate other strategies used for recall (Worthen & Hunt, 2011). In contrast, nonsignificant trends for larger effect sizes with respect to categorization strategies are consistent with prior research (Verhaeghen et al., 1992; Zehnder et al., 2010). Grouping items into a smaller number of chunks or semantic units based on shared attributes makes encoding and subsequent information retrieval easier (Bousfield, 1953; Craik, 1981; Hunt & Love, 1972). Older adults who use more categorical clustering on memory tasks remember more than those who use less categorization (Bower, 1970; Craik et al., 2007; Mandler, 1967). Previous research also indicates older adults benefit from strategies that involve visual imagery (Verhaeghen et al., 1992) because the occipital region of the brain, responsible for visual information processing, does not deteriorate with age as much as the frontal lobes (Hazlett et al., 1998; Nyberg et al., 2003). That the present review did not find a significant association for imagery is likely because of its wide-spread use and considerable between-study heterogeneity in how imagery training is applied.

The average retest effect in control groups reported in the present study (0.06 SD) is much smaller than that reported by Verhaeghen et al. (1992) (0.37 SD). There are two potential reasons for this discrepancy. First, Verhaeghen et al. (1992) selected only target memory measures that were most likely to show a training effect given the specific training provided. For example, training in number mnemonics would have precluded a word list-learning test from being included in effect size calculations. Because the present study's effect sizes incorporate a broader range of memory measures, some of which are less susceptible to practice effects than others, our effect size estimates are probably less affected by practice. Relatedly, the present study's estimates are also more conservative because aggregate effect sizes are likely to include some memory outcomes that are more invariant to training interventions. Further, research suggests retest effects for some memory tests decline with age (e.g., word list-learning tests; Shapiro & Harrison, 1990). Studies included in the present review tended to include older samples (mean ages ranged from 65 to 81.9 years) compared with studies in the review by Verhaeghen and colleagues (mean ages ranged from 61 to 78 years).

In addition to research implications, identification of specific memory strategies for memory improvement has consequences for clinical practice (Rebok, Parisi, Gross, et al., in press). In memory clinics where clinicians receive memory complaints and diagnose memory problems, evidence-based memory training practices and programs can provide guidelines for decision-making about appropriate treatment protocols. This review's findings present several options for patients who present with memory problems at such clinics and other health care settings. Importantly, identification of specific memory strategies may overlook self-generated, idiosyncratic, or hybrid techniques that are effective for some older adults, and so the present study's findings should not substitute for experienced clinical judgment or ignore a given patient's unique strengths and weaknesses.

Although the present study contributes to memory training research and practice, several caveats deserve comment. First, the review only includes published research studies. It does not include programs conducted in clinical or other settings or unpublished research trials, although efforts were made to contact potential authors of unpublished studies which led to inclusion of one eligible study (McDougall et al., 2010). Funnel plots revealed minimal evidence of publication bias. Further, a large intervention study among adults younger than 60 years using strategies common in commercially available cognitive training programs found similar training effect sizes (Owen et al., 2010), suggesting our results are valid.

Second, our inclusion criteria were stricter than previous studies of memory training. We felt justified in this because our criteria conform to published criteria for assessing psychological interventions (Weisz & Hawley, 2001), and because there is enough of a critical mass of memory training studies today we can afford to be selective. Another potential limitation is that, although the present analysis was limited to measures of memory exclusively, the measures are heterogeneous and reflect many types of memory (e.g., memory for numbers, lists, paragraph recall, visual memory). Despite this potential limitation, tests of heterogeneity suggested standardized differences in pre-post memory change between memory-trained and control groups were homogeneous across studies and meta-regressions were used to statistically account for unexplained between-study variance. Fourth, although the number of studies included in the present review is less than those in Verhaeghen et al. (1992) and thus might limit generalizability, the exclusion criteria relating to study design were more stringent to get as pure a sample of memory training studies as possible. Finally, the present review only considered studies among cognitively normal older adults. Other reviews have studied cognitive training in more cognitively impaired populations such as persons with dementia (Woods, Spector, Prendergast, & Orrell, 2006; Yu et al., 2009) and mild cognitive impairment (Belleville, 2008). Training among persons with dementia entails different training techniques than mnemonic training, including cognitive rehabilitation, spaced retrieval (Camp, 1989), or reality orientation therapy (Taulbee 1966; Woods et al., 2006).

Several areas of future research are indicated by the present meta-analysis. This study did not consider approaches that combined memory training with forms of pharmacotherapy (Yesavage et al., 2007), exercise (Colcombe & Kramer, 2003), or nutrition (Gonzalez-Gross, Marcos, & Pietrzik, 2001). Such combinations of approaches may be more effective than any single training program for promoting memory performance among older adults, a topic on which future investigation is merited (Hertzog et al., 2008; Studenski et al., 2006). Second, future studies should consider long-term memory benefits that may result from memory training. The ACTIVE study of healthy, community-dwelling older adults has provided evidence of long-term effects of memory training on memory outcomes as far as five years after training (Ball et al., 2002; Willis et al., 2006). However, few studies provide follow-up information beyond one year, and further research is needed to characterize the maintenance of memory training effects over time. Finally, future meta-analytic studies should investigate training effects on more distal measures of everyday functioning or other cognitive domains (e.g., everyday problem-solving, executive functioning, processing speed, language).

Concluding remarks

Public health is confronted with the confluence of three major challenges that will worsen in coming years: a greater number of older adults, rising prevalence of cognitive impairment in older adults, and increasing needs for health and long-term care services to accommodate this growing population segment who will experience cognitive decline. Against the backdrop of this looming predicament, researchers in public health and other fields study interventions that prevent or delay cognitive decline in late life. Memory training offers potential solutions to these public health challenges by helping individuals improve their everyday functioning through memory improvement (Hertzog et al., 2008). Maintenance of memory abilities is essential for the preservation of independence in older adulthood and also an influential factor in determining future care needs. Continued investigation of memory programs and interventions is needed to evaluate the effectiveness and generalizability of memory training interventions across different locations, populations, and age groups (Rebok et al., 2007).

There are several previous influential meta-analyses of memory training (Verhaeghen et al., 1992; Zehnder et al., 2009). Only four studies were in both our review and the one by Verhaeghen and colleagues (Flynn et al., 1990; Scogin et al., 1985; Yesavage et al., 1983, 1984). Two reasons for this lack of overlap are that many of our studies were published after 1992, and that the present review had different, and more stringent, inclusion criteria, per APA guidelines (Weisz & Hawley, 2001). The present review confirms and updates these other reviews and prior research that memory training is effective, and that although no particular strategy may be better than others, there is a trend towards larger improvement after training with more strategies. Consultations with clinicians and caregivers in the use of these training programs are vital to equip aging individuals with beneficial techniques that fit their lifestyles.

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	Overall pre-post effect size (95% CI)	Pre-post effect size, memory training (95% CI)	Pre-post effect size, control (95% CI)
Andrewes, 1996	0.08 (-0.54, 0.70)	0.69 (0.07, 1.31)	1.04 (0.38, 1.70)
Ball, 2002	0.26 (0.16, 0.36)	0.26 (0.16, 0.36)	-0.02 (-0.13, 0.08)
Becker, 2008	0.14 (-0.28, 0.55)	0.25 (-0.16, 0.66)	0.14 (-0.28, 0.55)
Best, 1992	1.55 (0.53, 2.57)	0.93 (-0.02, 1.88)	-0.66 (-1.58, 0.27)
Buschkuel, 2008	0.49 (-0.19, 1.16)	0.27 (-0.40, 0.94)	-0.19 (-0.85, 0.48)
Calero, 2007a	0.41 (0.02, 0.80)	0.19 (-0.20, 0.58)	-0.21 (-0.60, 0.18)
Calero, 2007b	0.54 (-0.00, 1.07)	0.23 (-0.30, 0.77)	-0.30 (-0.83, 0.23)
Calero-Garcia, 2007a	0.52 (-0.03, 1.08)	0.25 (-0.30, 0.79)	-0.25 (-0.80, 0.29)
Calero-Garcia, 2007b	0.53 (-0.09, 1.16)	0.17 (-0.45, 0.78)	-0.36 (-0.98, 0.26)
Caprio-Prevette, 1996	0.43 (0.06, 0.80)	0.68 (0.30, 1.05)	0.27 (-0.10, 0.63)
Carretti, 2007	0.55 (-0.19, 1.30)	0.61 (-0.14, 1.35)	-0.04 (-0.77, 0.69)
Craik, 2007	0.31 (-0.26, 0.87)	0.59 (0.02, 1.16)	0.14 (-0.43, 0.70)
Dahlin, 2008	0.74 (0.03, 1.46)	0.86 (0.13, 1.58)	0.47 (-0.23, 1.18)
Derwinger, 2005a	0.00 (-0.62, 0.62)	-1.02 (-1.68, -0.37)	-0.85 (-1.50, -0.20)
Derwinger, 2005b	0.24 (-0.38, 0.86)	-0.53 (-1.16, 0.10)	
Dunlosky, 2003	0.39 (-0.10, 0.88)	0.49 (-0.00, 0.99)	0.01 (-0.48, 0.50)
Fabre, 2002	0.51 (-0.48, 1.51)	0.22 (-0.76, 1.21)	0.01 (-0.97, 0.99)
Flynn, 1990	0.52 (-0.11, 1.16)	0.80 (0.16, 1.45)	0.26 (-0.36, 0.88)
Hill, 1990	1.78 (0.90, 2.66)	1.89 (1.00, 2.78)	-0.03 (-0.77, 0.71)
Hill, 1991a	0.51 (-0.10, 1.11)	0.74 (0.13, 1.35)	0.20 (-0.39, 0.80)
Hill, 1991b	0.08 (-0.49, 0.65)	0.28 (-0.29, 0.85)	
Hill, 1997	0.31 (-0.35, 0.96)	1.28 (0.56, 2.00)	1.07 (0.37, 1.76)
Lustig, 2008	-0.14 (-0.83, 0.56)	-0.13 (-0.82, 0.57)	0.07 (-0.62, 0.76)
McDougall, 2008	0.08 (-0.16, 0.32)	0.12 (-0.12, 0.36)	0.02 (-0.22, 0.26)
Mohs, 1998	0.06 (-0.27, 0.39)	-0.25 (-0.58, 0.08)	-0.34 (-0.68, -0.01)
Rapp, 2002	0.08 (-0.82, 0.98)	0.16 (-0.74, 1.06)	0.18 (-0.72, 1.08)
Scogin, 1985	0.26 (-0.32, 0.84)	0.43 (-0.16, 1.01)	0.15 (-0.43, 0.73)
Scogin, 1992	0.15 (-0.44, 0.74)	0.30 (-0.29, 0.89)	0.16 (-0.43, 0.74)
Scogin, 1998	0.29 (-0.31, 0.89)	0.70 (0.08, 1.33)	0.48 (-0.13, 1.09)
Smith, 2009	0.20 (0.03, 0.38)	0.39 (0.21, 0.57)	0.09 (-0.08, 0.27)
Stigsdotter, 1989	0.46 (-0.43, 1.35)	0.33 (-0.56, 1.21)	-0.14 (-1.02, 0.73)
Woolverton, 2001a	0.41 (-0.15, 0.97)	0.50 (-0.06, 1.07)	0.08 (-0.47, 0.64)
Woolverton, 2001b	0.85 (0.26, 1.44)	0.97 (0.37, 1.57)	0.08 (-0.48, 0.65)
Yesavage, 1983	0.38 (-0.18, 0.94)	1.94 (1.27, 2.62)	0.56 (-0.01, 1.12)
Yesavage, 1984	0.64 (-0.01, 1.28)	0.94 (0.28, 1.60)	0.30 (-0.33, 0.93)

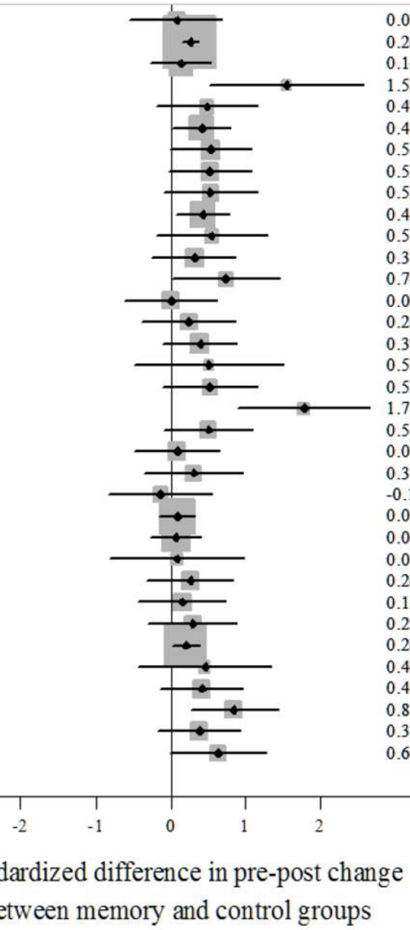

Figure 1. Forest Plot of Effect Sizes

Legend. Effect sizes representing retest-adjusted standardized differences (in standard deviation units) in pre-post memory change between memory-trained and control groups are graphed. Training and control group-specific effect sizes are also provided in columns at right. Control effect sizes are not shown for two studies because the same control group was used to compare against more than one memory training intervention.

95% CI: 95% confidence interval.

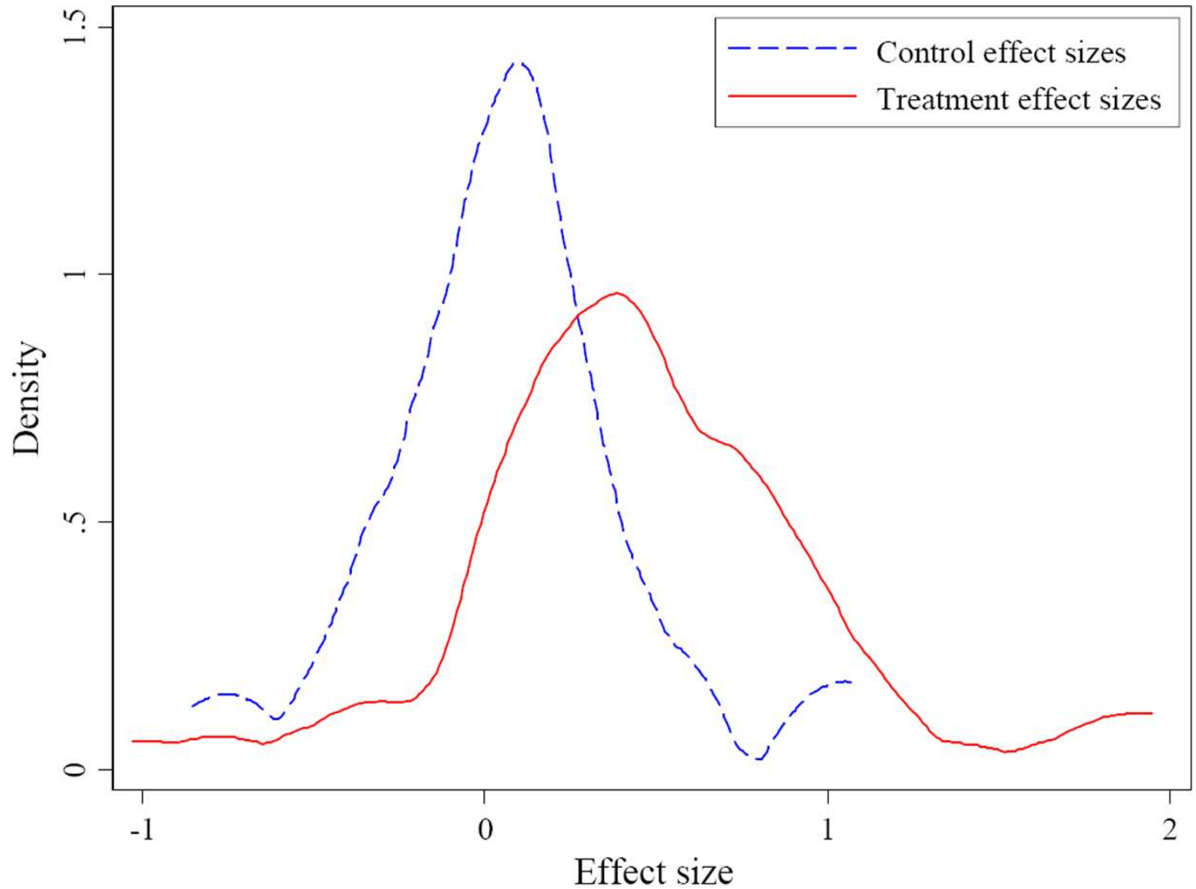

Figure 2. Distribution of Study Effect Sizes by Training Status

Legend. Effect sizes represent standardized pre-post changes (in standard deviation units) in memory for memory-trained and control groups.

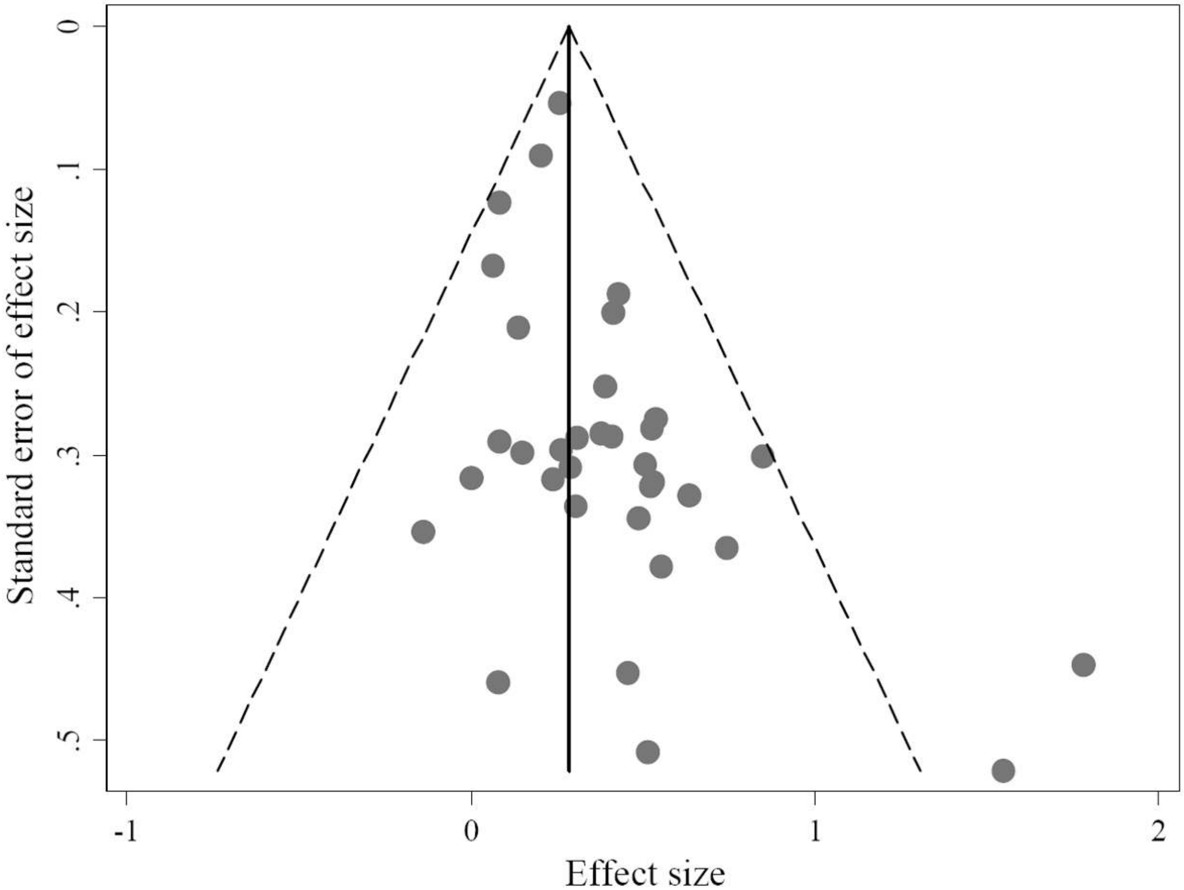

Figure 3. Funnel Plot of Effect Sizes with Pseudo 95% Confidence Intervals

Legend. Effect sizes represent retest-adjusted standardized differences (in standard deviation units) in pre-post memory change between memory-trained and control groups. Diagonal dotted lines represent 95% confidence intervals of the expected distribution of studies around the mean memory effect size estimate for each standard error on the ordinate, assuming no between-study heterogeneity. They are referred to as pseudo because the lines are not strict confidence limits.

Table 1

Descriptive Statistics of 35 Studies Included in the Meta-Analysis

Variable		Range
Sample age, mean (SD)	72.7 (4.4)	65, 81.9
Number of sessions, mean (SD)	10.5 (8.0)	1, 40
Number of hours, mean (SD)	12.8 (9.2)	0.5, 42
Completed training, % (SD)	90.0 (10.0)	56, 100
Randomization, number of studies (%)	26 (72.2)	
Placebo versus no-contact control, n (%)	13 (36.1)	
Internal mnemonic strategies, n (%)		
Method of Loci	15 (42.9)	
Association	14 (40.0)	
Categorization	15 (42.9)	
Visual imagery	23 (65.7)	
Face-name / Name-learning	20 (57.1)	
Rehearsal	3 (8.6)	
Attention	10 (28.6)	
Number mnemonics	6 (17.1)	
Story mnemonics	2 (5.7)	
External memory aids	10 (28.6)	
Number of strategies trained, n (%)		
1	10 (28.6)	
2-3	11 (31.4)	
4-5	7 (20.0)	
6-7	7 (20.0)	

Note. Marginal counts of strategies used in particular studies add up to more than the 35 studies included in the present review because most studies taught multiple strategies. Nonrandomized controlled studies were included that used block randomization or matching procedures to identify a comparable control group.

n: number of studies; SD: standard deviation.

Table 2

Overall and Treatment-Specific Group Effect Size Estimates

	Effect size	95% CI	Number of participants at post-training	Number of studies	Q statistic			I^2
					χ^2	Degrees of freedom	p-value	
Overall	0.31	(0.22, 0.39)	3797	35	38.41	34	0.24	12.40%
Training	0.43	(0.29, 0.57)	1930	35	107.03	34	<0.001	68.20%
Control	0.06	(-0.05, 0.16)	1867	33	50.22	32	0.02	36.30%

Legend. The overall effect size represents the difference in standard deviation units in pre-post memory change between memory-trained and control groups. Effect sizes specific to training groups represent standardized pre-post changes (in standard deviation units) in memory for the group of studies.

95% CI: 95% confidence interval.

Table 3

Meta-regressions of Effect Sizes on Selected Predictors

Predictor	Pre-post effect size	
	β	95% CI
Sample age	-0.01	(-0.03, 0.01)
Number of hours	0.00	(-0.01, 0.00)
Percent who completed training	-0.34	(-1.19, 0.51)
Placebo versus no-contact control	-0.10	(-0.25, 0.06)
Internal mnemonic strategies		
Method of Loci	0.10	(-0.06, 0.26)
Association	0.07	(-0.10, 0.23)
Categorization	0.17 *	(0.00, 0.33)
Visual imagery	0.06	(-0.12, 0.24)
Face-name / Name-learning	0.00	(-0.17, 0.17)
Rehearsal	0.38 *	(0.02, 0.75)
Attention	0.09	(-0.08, 0.27)
Number mnemonics	0.16	(-0.08, 0.41)
Story mnemonics	0.12	(-0.35, 0.58)
External memory aids	0.15	(-0.05, 0.35)
Number of strategies trained	0.04 *	(0.00, 0.07)

Legend. Effect sizes represent retest-adjusted standardized differences (in standard deviation units) in pre-post memory change between memory-trained and control groups from random effects regressions of effect sizes on covariates. Because of the small sample size (35 studies), separate regressions were performed for each of the 15 predictors.

* $p \leq 0.05$. No coefficients were significantly associated with effect sizes after applying a Bonferroni adjustment for multiple tests (adjusted α=0.003).

95% CI: 95% confidence interval.