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Does Strategy Training Reduce Age-Related Deficits in Working Memory?

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Abstract

Background—Older adults typically perform worse on measures of working memory (WM) than do young adults; however, age-related differences in WM performance might be reduced if older adults use effective encoding strategies (Bailey, Dunlosky, & Hertzog, 2009).

Objective—The purpose of the current experiment was to evaluate WM performance after training individuals to use effective encoding strategies.

Methods—Participants in the training group (older adults: n = 39; young adults: n = 41) were taught about various verbal encoding strategies and their differential effectiveness and were trained to use interactive imagery and sentence generation on a list-learning task. Participants in the control group (older: n=37; young: n=38) completed an equally engaging filler task. All participants completed a pre-training and post-training reading span task, which included self-reported strategy use, as well as two transfer tasks that differed in the affordance to use the trained strategies – a paired-associate recall task and the self-ordered pointing task.

Results—Both young and older adults were able to use the target strategies on the WM task and showed gains in WM performance after training. The age-related WM deficit was not greatly affected, however, and the training gains did not transfer to the other cognitive tasks. In fact, participants attempted to adapt the trained strategies for a paired-associate recall task, but the increased strategy use did not benefit their performance.

Conclusions—Strategy training can boost WM performance, and its benefits appear to arise from strategy-specific effects and not from domain-general gains in cognitive ability.

Keywords

working memory; strategy use; aging; training; transfer effects

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Working memory (WM) is a limited capacity system in which information is simultaneously maintained and manipulated. The ability to process information in working memory is highly indicative of other higher-order cognitive abilities, such as fluid reasoning and reading comprehension (e.g., Daneman & Merikle, 1996; Kane, Hambrick, & Conway, 2005). The importance of WM processing for supporting other cognitive abilities has been demonstrated in children with attention-deficit/hyperactivity disorder (e.g., Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), college students (e.g., Ackerman, Beier, & Boyle, 2005), patient populations with compromised brain function (e.g., McAllister, Sparling, Flashman, Guerin, Mamourian, & Saykin, 2001), and in cognitively healthy older adults (e.g., Hasher & Zacks, 1988, Salthouse & Babcock, 1991). Typically, WM is measured by complex span tasks, which involve a storage component and a concomitant processing component. One widely used complex span task is the Reading Span (RSPAN) task. In a common version of this task (Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004), participants are instructed to determine the accuracy of a sentence and then commit an independent but simultaneously presented item (e.g., a word or letter) to memory. Following a varying number of sentences, participants are prompted to recall the to-be-remembered items in serial order. WM performance can be scored as the highest amount of items that an individual successfully recalled or as the proportion of correctly recalled items across trials. In either case, individuals differ widely in their performance on these tasks, indicating variability in WM span. Those persons who remember longer series of words are often referred to as *high spans*, and those who remember shorter series are referred to as *low spans*.

Why does WM capacity differ amongst individuals, and why does it decline with age? Individual and age-related differences in WM performance partly arise from age changes in functional integrity of brain regions critical for storage, maintenance, and retrieval of information (Grady, 2012). Age-related changes in brain integrity can result in slowing of information processing speed (e.g., Salthouse, 1994) or in the ability to inhibit no-longer relevant or task-irrelevant information from WM (Hasher & Zacks, 1988). Individual and age-related differences in WM performance also are associated with the ability to employ effective encoding strategies on WM tasks (Cokely, Kelley, & Gilchrist, 2006; Dunlosky & Kane, 2007). From a theoretical perspective, encoding can influence working memory performance because elaborative encoding strategies can boost recall of verbal materials that serve as the memoranda for WM tasks (Richardson, 1998). A sizeable portion of individuals – even low spans –spontaneously use effective encoding strategies on some WM span trials (Bailey et al., 2009; Bailey, Dunlosky, & Kane, 2008; 2011; Unsworth & Spillers, 2010), but they do not use effective strategies on all trials. Thus, from an empirical perspective, individual differences in how often people use effective strategies across trials is positively related to performance on WM tasks (e.g., Dunlosky & Kane, 2007). The reasons for this pattern are not yet clear, but it does suggest adults can improve their WM performance if they use more effective strategies on a greater proportion of WM trials.

Although spontaneous use of effective strategies in WM tasks accounts for a significant proportion of variance (i.e., individual differences) in WM performance, it accounts for only a small portion of the age-related variance (Bailey et al., 2009; Touron, Oransky, Meier, &

Hines, 2010). Bailey et al. (2009) had young and older adults complete verbal WM span tasks and then report which encoding strategies they used on each trial. Older adults reported using effective encoding strategies (e.g., using mental imagery) on a similar proportion of trials as did the young adults, and differences in recall on these trials were somewhat smaller between young and older adults. Importantly, older adults used effective strategies on only about one-third of the span-task trials and used a less effective strategy (i.e., rote repetition) or no strategy on the majority of trials (see also Touron et al., 2010). Put differently, older adults perform more like young adults when they use effective strategies to encode information on WM span tasks, but they perform disproportionately worse than do young adults on the trials in which less effective encoding strategies are used. The pattern of effects in Bailey et al. (2009) raises the following questions: Could older adults benefit from using effective strategies more often on a span task, and how much could improving the use of effective strategies reduce age differences in WM performance?

Towards answering these questions, the main goal of the current experiment was to evaluate whether strategy training improves working memory performance in older adults. Strategy training is one instance of a broader approach to training that can also be referred to as *process-specific training* – i.e., training individuals to improve their implementation of specific cognitive process that can improve cognitive performance on tasks that afford its use. For instance, training older adults the method of loci involves training a specific process (e.g., mental imagery) that can improve performance for tasks that afford imagery (e.g., learning concrete words) but would benefit performance little – if any – on tasks that do not afford imagery (e.g., learning abstract concepts). Such an approach can be contrasted with *domain-general training*, which often provide task practice that target general cognitive processes and mechanisms that promise to promote domain-general gains in performance across many tasks. Although many intervention studies use domain-general WM training (including simply providing extensive WM task practice) to evaluate how WM can be improved, only one other study (described below) has explicitly examined whether strategy training influences older adults' WM performance.

We view the distinction between strategy training and domain-general WM training as a critical one. Strategy training involves teaching techniques to help individuals more effectively encode, maintain, and recall information that can be effective for a WM span task. In contrast, domain-general WM interventions seek to use task practice to improve target processes such as attention and inhibition to help individuals increase their functional WM capacity (e.g., through learning to ignore distracting information; Kane & Engle, 2003). Domain-general WM interventions are often referred to as WM training paradigms, but they typically involve practice with multiple tasks that theoretically engage WM processes, cover multiple modalities, and require frequent memory updating (e.g., complex span tasks, updating tasks, N-back tasks, etc.; see Morrison & Chein, 2011, for a review). Overall, this type of WM practice has proven fairly successful in improving span performance in the practiced task context (e.g., Li, Schmiedek, Huxhold, Röcke, Smith, & Lindenberger, 2008; Schmiedek, Lövdén, & Lindenberger, 2010; Zinke, Zeintl, Eschen, Herzog, & Kliegl, 2011) and, in some cases, in improving performance on unpracticed WM transfer tasks (e.g., Schmiedek et al., 2010; for a review of WM training, see Chein & Morrison, 2010 for an opposing view see Shipstead, Redick, & Engle, 2012). However, these WM studies typically do not train specific strategic processes that can help people to remember the target span list, whereas studies that incorporate strategy training do exactly that.

In the current study, we used a strategy training approach – training adults to use *normatively effective* encoding strategies, such as interactive imagery and sentence generation. We refer to these strategies as normatively effective strategies because memory performance is higher when these strategies are used during encoding as compared to when less elaborative strategies or rote rehearsal are used (for reviews, see Hertzog, McGuire, & Lineweaver, 1998; Richardson, 1998). Critically, we did not explicitly train strategy use in the WM task context itself. Instead, we provided general training on how to use encoding strategies, and then later introduced trainees to a WM task that afforded an opportunity to use the trained strategies. Although spontaneous strategy use at encoding influences recall performance on WM tasks (e.g., Dunlosky & Kane, 2007), we could find that strategy training does not improve older adults' overall WM performance for at least two reasons. First, individuals may not perceive the strategy training as being relevant for the WM task, and therefore may not employ the trained strategies in that task. Second, the trained strategies might be difficult for older adults to implement in the WM task context. WM span tasks are fast-paced and place substantial demands on cognitive control processes (Kane & Engle, 2003) so perhaps some people (and in particular, older adults) will not have enough time or resources available to implement newly-learned strategies. It may be the case that only people with initial higher WM capacity benefit from strategy training (Cokely et al., 2006; Dunlosky & Kane, 2007; Naumann, Richter, Christmann, & Groeben, 2008). If so, age-related differences in WM span could even increase after strategy training (e.g., Kliegl, Smith, & Baltes, 1989).

Despite these possibilities, our main hypothesis was that training effective encoding processes would improve WM span performance for older adults by increasing the likelihood of effective strategy use. First, strategy training has been used extensively in episodic memory tasks and has been successful in improving older adults' memory performance (see Gross et al., 2012 for a review). Second, manipulations targeting strategy use in WM tasks, including instructions to use strategies (Turley-Ames & Whitfield, 2003) and explicit WM strategy training (McNamara & Scott, 2001) have also successfully improved younger adults' WM performance. Finally, strategy training also has been effective for populations with reduced or impaired WM capacity, such as young children (St. Clair-Thompson, Stevens, Hunt, & Bolder, 2010), children with reading disabilities (Swanson, Kehler, & Jerman, 2010), and patients with mild traumatic brain injury (Cicerone, 2001).

To our knowledge, Carretti, Borella, and De Beni (2007) reported the only study that involved training encoding strategies to improve WM performance in older adults. Their young and older adults completed the interactive imagery training regimen devised by McNamara and Scott (2001). Training consisted of three sessions that took approximately 30-60 minutes each. During each training session, participants practiced using interactive imagery to encode four lists of words and then rated the quality of their images following recall. Transfer of training was assessed using the categorization WM span task (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998). Participants' performance on the WM task significantly improved from pre- to post-training tests, and improvements were comparable across both age groups. However, Caretti et al. (2007) did not directly measure strategy use in the WM task, so it is unclear whether their training benefits arose specifically from increased use of effective strategies, from improved implementation of strategies, or were generated by some other unknown variables activated by the training.

The current study extended and further evaluated the finding that strategy training improves WM performance. The training procedures were implemented to help older adults use elaborative encoding strategies more frequently and more effectively. We trained participants to use more than one effective encoding strategy rather than just training them to use interactive imagery as in Caretti et al. (2007). Given that some individuals prefer to use a visual strategy and others prefer a verbal strategy (Marks, 1973; Paivio, 1971), we trained all individuals to use both interactive imagery and sentence generation in an episodic memory task context – free recall of word lists. In addition to practicing the strategies, participants also learned about the various verbal encoding strategies and their differential effectiveness. Recent evidence has demonstrated that people incorrectly believe that relatively ineffective strategies such as rote repetition promote learning (e.g., Hertzog, Price, & Dunlosky, 2008), which contributes to the age-related deficit in WM (Bender & Raz, 2012). Thus, we predicted that instruction about the efficacy of verbal encoding strategies in conjunction with strategy training on word lists would improve strategy use. The key questions were (1) whether people would generalize this kind of strategy training to the WM task context, (2) whether the strategies would influence WM performance, and (3) whether the trained strategies would reduce age-related deficits in WM performance.

Given that we trained participants to use multiple strategies, it was important to evaluate which strategies they used. As in Bailey et al. (2009), we directly evaluated whether participants implemented the trained strategies by collecting a strategy report immediately after each WM span trial (for evidence supporting the validity and non-reactivity of this measure, see Dunlosky & Kane, 2007). This approach allowed us to address the question of whether trained encoding strategies were generalized to the WM task.

Finally, we evaluated whether the trained encoding strategies would also transfer to a task that affords their use (i.e., a paired-associate cued-recall task) in contrast to a task that in theory should not benefit from encoding strategies [i.e., the Self-Ordered Pointing Task (SOPT)]. The SOPT is a measure of executive function that involves choosing a different abstract shape on each trial. Thus, we did not expect verbal encoding strategies to be effective for maintaining and updating abstract shapes. If strategy training increases strategy use as well as strategy effectiveness that generalizes to other task contexts, then participants in the training group should outperform those in the control group on the paired associate task. However, we did not expect training group differences on the SOPT because its materials are not amenable to organizational encoding strategies.

Method

Participants

Seventy-six older adults were recruited through a newspaper advertisement in northeast Ohio. Seventy-nine young adults recruited from introductory psychology courses at Kent State University participated to complete a course requirement. The older adults completed a phone interview and were excluded from the current study if they had a history of dementia, stroke, other neurological disorders, or the use of medications for memory problems. Participants were randomly assigned to one of two groups (strategy training or control). Of the 76 older adults, 39 (24 female) were assigned to the training group and 37 (31 females) were assigned to the control group. Of the 79 young adults, 41 (31 female) were assigned to the training group and 38 (22 female) were assigned to the control group. Demographic variables for each group are presented in Table 1. Typical age differences were observed: Young adults performed better on the letter comparison task, whereas older adults performed better on a vocabulary test (Ekstrom, French, Harman, & Dermen, 1976). Each older adult was paid $20 and each young adult received course credit for their participation.

Materials

Reading span (RSPAN) task—We used a modified version of the RSPAN task from Kane et al. (2004). In this task, participants read a sentence aloud (e.g., "Mr. Owens left the lawnmower in the lemon."), reported whether it was logical or illogical, and then read an unrelated, to-be-remembered word aloud (e.g., EAGLE). Once the word was read aloud, the next sentence appeared on-screen. After presentation of the final sentence-word pair of each trial, participants were instructed to recall the target words in serial order. This task consisted of 16 experimenter-paced trials that ranged from three to six sentence-word pairs. The words and the order of set sizes were randomized, and the same order was used for all participants. Following recall on each trial, participants completed a strategy report. We used the set-by-set strategy reports created by Dunlosky and Kane (2007), in which the participant indicated how they attempted to remember the words at that particular trial by choosing one of the six strategy options: Reading, repetition, sentence generation, imagery, grouping, or a different strategy. Note that participants could report not using any strategy by choosing the "reading" option (i.e., they read the to-be-remembered word according to the instructions but did not use any further encoding strategy). The validity of these reports has been empirically demonstrated, and the reports have negligible reactive effects on WM span performance (Bailey et al, 2009; Dunlosky & Kane, 2007; Touron et al., 2010).

Participants completed two versions of each task, and the order of administration (i.e., version A versus version B) was counterbalanced across participants' pre-training and post-training tests. Performance was computed using partial-credit unit scoring (for details, see Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). That is, performance on each trial was scored as the proportion of correctly recalled items (e.g., trial 1: 3/4 = .75, trial 2: 3/3 = 1, and trial 3: 4/6 = .67), and overall performance was expressed as the mean proportion of correctly recalled items [e.g., (.75 + 1 + .67)/3 = .81)].

Strategy training task—Participants in the training group worked individually to complete a self-paced strategy-training procedure. In the first part this procedure, they learned about how human memory can be affected by the use of different strategies. They learned about the different strategies afforded by verbal materials (e.g., rote repetition, imagery, and sentence generation) and about the differential effectiveness of these strategies. In the next part, they learned how to use interactive imagery and sentence generation properly when trying to memorize a list of words. That is, they were given a list of words (e.g., PONY, DRESS, COINS, TULIP) and were given an example of how to implement interactive imagery (e.g., "You could picture a PONY wearing a big DRESS made only out of COINS who is trying to balance all of its weight on one TULIP.") In the final part, they practiced using these strategies on a list-learning task in which words were presented one at a time onscreen for 2 seconds apiece with a 1 second intertrial interval. They were encouraged to use the strategies to help them remember the words. After the final word on each trial, participants attempted to recall the words in serial order. The practice trials began with sets of only 3 words and gradually increased to sets of 6 words. Following the practice trials with 6 words, participants received more practice trials, but the length of the word lists were presented in a random order. Participants completed a total of 18 practice trials. After completing the training procedure, the participants were told that they could use the effective encoding strategies to help improve their memory performance on the remaining tasks. Note that the task used during the training procedure was not a WM span task because it did not involve a secondary task (e.g., solving equations or reading sentences), but the training task was similar to the storage component of the RSPAN task (i.e., learning and recalling words in serial order). On average, the strategy training procedure took 20.37 minutes for older adults (range = 12.01 – 38.84 min) and 12.72 minutes for young adults (range = 9.41 – 21.08 min).

Filler task—Participants in the control group completed an equally engaging task. This task involved learning to classify birds. More specifically, the pictures of 6 exemplars (e.g., song sparrow, house sparrow, white-crowned sparrow) from 12 bird families (e.g., sparrow, swallow, vireo) were presented individually. Each bird was presented with its family name (e.g., a house sparrow was presented with the label "Sparrow"), and the order of birds for presentation was randomized anew for each participant. During study, the participant could study each bird as long as she or he wanted, and then after studying each bird, the participant predicted the likelihood that they would correctly classify the bird on the upcoming test. After studying all birds, 48 novel birds (4 birds from each of the 12 families) were presented without labels, and participants were asked to classify each one by selecting its family name (all 12 family names were listed below the to-be-classified bird). After the classification of novel exemplars, the previously studied birds were presented for classification (details of this procedure are presented in Wahlheim, Dunlosky, & Jacoby, 2011). Moreover, although the task may involve associative processing (i.e., attempting to associate pictures of bird exemplars and their family name while learning each bird category), the processes would unlikely promote the generation of associative mediators that were the focus of our strategy training. Thus, this task was chosen because it is engaging, it required approximately as much time as the strategy training to complete, and it would require a different kind of associative processing than demanded by the use of trained mnemonics.

Transfer tasks—We assessed whether the trained strategies benefited working memory performance as well as other cognitive tasks. In particular, participants completed a paired-associate cued-recall test that afforded the use of the trained strategies and the self-ordered pointing task that did not afford their use. Given time limitations of this single-session intervention, we did not administer the transfer tasks prior to training. Nevertheless, given random assignment (which resulted in groups of participants with closely matched demographics), any post-training differences between groups are interpretable.

Paired-associate cued-recall test—Participants studied 40 unrelated word pairs (e.g., DOCTOR – LOBSTER) presented on the computer screen at a 5-second rate. During the recall phase, the cue (e.g., DOCTOR) was presented and participants typed in the correct response (e.g., LOBSTER). Following recall, participants were presented with the list again, and completed a strategy report in which they recounted which specific strategy (passive reading, rote repetition, interactive imagery, sentence generation, or "other") they had used to study each word pair (Dunlosky & Hertzog, 2001).

Self-ordered pointing task (SOPT)—Participants also completed the SOPT, a measure of executive functioning (Petrides & Milner, 1982). In this task, 16 abstract shapes were presented on the computer screen. Participants were instructed to choose one shape, and after they made their choice, the next screen appeared. This screen contained the same 16 shapes but they were rearranged in a different order. Participants again were instructed to choose one shape and to try not to choose that same shape again. No time limit was used. Trials in which a previously selected shape were reselected were scored as perseveration errors; performance was scored as the proportion of errors committed (e.g., total number of errors ÷ 16).

Procedure

After signing the consent form, participants completed a demographics questionnaire and the pre-test RSPAN task. Next, participants in the training group completed the strategy training, whereas participants in the control group completed the filler task. Then all participants completed the post-test RSPAN task, the paired-associates cued-recall task, and the SOPT. Finally, participants in the training group completed the strategy questionnaire.

Results

Each variable was screened for values more than 3.5 standard deviations different from the sample mean, and no value met this criterion. All variables were approximately normally distributed (skewness < |1.5|, kurtosis < |1.5|). In addition to statistical significance tests, we also report Cohen's (1988) d as an estimate of the effect size of differences in means, scaled as SD unit differences. Typical benchmarks are $d \leq 0.2$ for a small effect, $d \approx .5$ for a medium-sized effect, and $d \geq 0.8$ for a large effect.

First, we evaluated pre-training RSPAN performance for young and older adults in the control and training groups, and then we compared their post-training RSPAN performance. We then examined whether participants implemented the trained strategies on the post-training RSPAN task, and if so, whether the strategy lesson and practice increased the use of effective strategies as well as their effectiveness. Finally, we report performance on the transfer tasks.

RSPAN

Span performance—Prior to strategy training (Figure 1), young adults significantly outperformed older adults on the RSPAN task, $t(155) = 2.07$, $p = .02$. To evaluate the effects of strategy training, we conducted a 2 (Age: young vs. old) × 2 (Group: control vs. training) × 2 (Test: pre-training vs. post-training) mixed ANOVA on RSPAN performance. The main effect of Test was significant, $F(1,151) = 42.69$, $p < .001$, $\eta^2 = .28$, but neither the main effect of Age, $F(1,151) = 3.48$, $p = .064$, $\eta^2 = .02$, nor the main effect of Group, $F < 1$, were significant. As evident from inspecting Figure 1, the Group × Test interaction was highly significant, $F(1,151) = 26.82$, $p < .001$, $\eta^2 = 18$, indicating that span performance improved significantly more from pre- to post-test for participants in the training group than in the control group. The Age×Test, Age × Group, and Age × Group × Test interactions were not significant (*F*s < 1.0, *p*s > .56). Consistent with outcomes from the omnibus ANOVA, both the young and older adults in the training group showed medium training effect sizes ($d = 0.54$ and $d = 0.60$, respectively), whereas the improvements made by the young and older adult controls were near zero ($d = 0.04$ and $d = 0.08$, respectively). These results suggest that both young and older adults benefitted from the strategy training. As a consequence, the post-test reduction in age-related differences was rather modest; that is, the small age-related difference in WM span performance at pretest ($d = .33$) was not eliminated at posttest ($d = 0.25$), as shown in Figure 1.

Effective strategy rates—Did participants in the training group use the encoding strategies they learned during the training phase and apply them on the post-training RSPAN task? We evaluated whether participants reported using effective strategies on a higher proportion of trials on the post-training than on the pre-training RSPAN task. To do so, we first computed the mean proportion of span-task trials that each participant reported imagery and sentence generation (which are the normatively effective strategies), and then we averaged across all participants (see Table 2). On the pre-training RSPAN task, participants reported using effective encoding strategies on approximately 30% of the RSPAN trials, which is similar to the pattern of reported strategy use from previous studies (Bailey et al., 2008; 2009; Dunlosky & Kane, 2007).

A 2 (Age: young vs. older) × 2 (Group: control vs. training) × 2 (Test: pre-training vs. post-training) mixed ANOVA revealed significant main effects of Group, $F(1,151) = 3.92$, $p < .048$, $\eta^2 = .03$, and Test, $F(1,151) = 72.97$, $p < .001$, $\eta^2 = 0.48$. The main effect of Age was not significant, $F(1,151) = 2.15$, $p = .15$, $\eta^2 = 0.01$, and this lack of significant age-related differences in effective strategy use replicated the results in Bailey et al. (2009). The Group × Test interaction also was highly significant, $F(1,151) = 47.31$, $p < .001$, $\eta^2 = 0.31$, indicating that strategy use on the RSPAN task increased significantly more from pre- to post-training for participants in the training group than in the control group. This training-related increase in effective strategy use was significant for both the young adults, $t(40) = 5.68$, $p < .001$, $d = 0.54$, and older adults, $t(38) = 4.96$, $p < .001$, $d = 0.78$. In contrast, strategy use did not change for young and older adults in the control group (*ts* < 1.3, *p*s > .

11). The Age × Test, Age × Group, and Age × Group × Test interactions were not significant (*F*s < 1.0, *ps* > .35).

We also evaluated individual differences in WM performance as a function of degree of increase in effective strategy use. Increases in effective strategy rates (i.e., the change in proportion of effective strategies used from pre- to post-training) significantly correlated with the change in WM performance for the entire sample (see Figure 2), $r = 0.43$, $p < .001$ (young: $r = .51$, $p < .001$; older: $r = .35$, $p = .001$). This correlation was numerically stronger in the training group, $r = 0.34$, $p = .001$, than it was in the control group, $r = 0.20$, $p = .04$, but this difference in correlations was not statistically significant using a normal deviate test after Fisher's r-to-z transformation, $z = 0.92$, $p = .18$. Thus, individuals' increasing strategy use in either condition also was related to improved WM performance.

Strategy efficacy—Participants in the training group reported using the target strategies more often on the post-training RSPAN task, but did they also use them more effectively? To answer this question, we assessed performance on trials in which participants reported using the effective strategies (interactive imagery and sentence generation) on the pre-training and post-training RSPAN tasks. These strategy efficacy measures are reported separately for young and older adults in the control and training groups in Table 3.

We conducted a 2 (Age: young vs. old)×2 (Group: control vs. training)×2 (Test: pre-training vs. post-training) ANOVA on WM performance for trials on which effective strategies were reported. We observed a significant main effect of Age, $F(1,88) = 7.52$, $p = .007$, $\eta^2 = .09$. Further, the main effect of Test was significant, $F(1,88) = 9.75$, $p = .002$, $\eta^2 = .11$, with participants using strategies more effectively at the post-training test. However, the main effect of Group was not significant nor were the Age × Group, Age × Test, Group × Test, and Age × Group × Test interactions.

Transfer effects

Strategy training on freely recalled lists of words improved WM span performance. Are these training gains due to more efficient strategy use or to improved domain general executive control processes? To answer this question, we compared performance on two transfer tasks – one that affords the use of strategies similar to the trained strategies (i.e., paired associate recall) and one that does not afford the use of similar strategies but assesses executive control processes (i.e., SOPT). We first present analyses on the paired-associate recall performance and then on the SOPT performance.

Paired-associate cued-recall—Paired-associate recall is presented in Table 4. A 2 (Age: young vs. old) × 2 (Group: control vs. training) ANOVA showed a significant main effect of Age, $F(1,108) = 18.78$, $p < .001$, $\eta^2 = 0.17$; however, the main effect of Group was not significant nor was the Age×Group interaction, *F*s < 1. Although strategy training did not affect paired-associate recall in the young adults, we observed a trend towards higher recall for the trained older adults, $t(55) = 1.42$, $p = .08$, $d = 0.38$.

Given that we had collected strategy reports for this task, we examined whether participants in the training group attempted to apply the trained strategies to this task. Again, we first computed the mean proportion of trials that each participant reported imagery and sentence generation, and then we averaged across participants. Average proportion of trials that participants reported using effective strategies on the paired-associate recall task is presented in Table 4. We conducted a 2 (Age: young vs. old)×2 (Group: control vs. training) ANOVA on the proportion of trials that participants reported using effective strategies. The main effect of Group was significant, $F(1,108) = 5.79$, $p = .018$, $\eta^2 = 0.05$, indicating that participants in the training group reported using the trained strategies more often on this transfer task than did participants in the control group. The main effect of Age and the Age×Group interaction were not significant, $F(1,108) = 2.31$, $p = .13$, $\eta^2 = 0.02$. Finally, we examined performance on the trials on which participants reported using effective strategies (see Table 4). A 2 (Age: young vs. old)×2 (Group: control vs. training) ANOVA revealed main effects of Age, $F(1,108) = 12.71$, $p = .001$, $\eta^2 = 0.15$, and Group, $F(1,108) = 4.45$, $p = .038$, $\eta^2 = 0.05$. On trials in which effective strategies were reported, younger adults outperformed older adults and, unexpectedly, participants in the control group outperformed participants in the training group; however, the Age×Group interaction was not significant, $F < 1$.

We also calculated the correlation between the proportion of effective strategy use and recall performance on the paired-associate task. Across the entire sample, there was a strong correlation, $r = .73$, $p < .001$, indicating that individuals who reported using effective strategies on more trials also performed better on paired-associate recall.

SOPT—Average number of errors made on SOPT by age group and training group are presented in Figure 3. A 2 (Age: young vs. old)×2 (Group: control vs. training) ANOVA revealed only a significant main effect of Group, $F(1,105) = 5.76$, $p = .018$, $\eta^2 = .05$, with participants in the training group committing more errors than those in the control group. Neither the main effect of Age nor the Age×Group interaction were significant, *Fs* < 1.

Discussion

The vast majority of WM training studies provide extensive WM task practice as a basis for improving performance (e.g., Schmiedek et al, 2010). In contrast, the present study provided no WM task training, but instead trained participants to use mnemonic strategies relevant to enhancing WM span performance (Dunlosky & Kane, 2007). Our goals were to evaluate whether training young and older adults to use encoding strategies would (1) increase the frequency of their use on WM span tasks, (2) generate improvements in WM span performance and (3) transfer to performance on other cognitive tasks. Regarding the first goal, participants in the training group reported using effective strategies significantly more often than controls after training (Table 2), and this increase was related to improvements in their WM performance (Table 3). Thus, the present results show that training individuals in the use of effective verbal encoding strategies benefits WM performance, which replicates and extends the previous study that examined this issue (Caretti et al., 2007).

Regarding the second goal, we found that prior to training both younger and older adults report using effective encoding strategies on approximately one-third of the span task trials (see also Bailey et al., 2008; 2009; Dunlosky & Kane, 2007). Furthermore, both young and older adult's WM recall performance improved after strategy training, without having much of an effect on age-related differences in WM performance. The magnitude of age differences observed here were smaller than might be expected from the larger literature (e.g., Verhaeghen & Salthouse, 1997). Further, the age similarity in effective strategy use prior to training may partially explain why strategy training did not greatly impact age-related differences in WM performance.

The age-equivalence in training gains we observed in the current study was similar to those reported in some studies implementing domain-general training (e.g., Bherer, Kramer, Peterson, Colcombe, Erickson, & Becic, 2005; Li et al., 2008; Richmond, Morrison, Chein, & Olson, 2011; von Bastian, Langer, Jäncke, & Oberauer, 2013). Other studies using domain-general training, however, have reported larger gains in young adults as compared to older adults (e.g., Brehmer, Westerberg, & Bäckman, 2012; Dahlin, Stigsdötter Neely, Larsson, Bäckman, & Nyberg, 2008; Heinzel et al., 2013; Schmiedek et al., 2010). One reason differential training gains are observed across age groups may be due to the degree to which older adults can implement the trained process. Previous work has shown that training gains depend on the compliance of the older adults (Bagwell & West, 2008). That is, successful implementation of training depends on the degree to which older adults can or will expend the effort to fully implement or adapt a process to meet the demands of a task. Perhaps the trained process in the current study (i.e., creating mediators) was easy enough for older adults to master, which increased compliance and led to age-equivalence in training gains (Bagwell & West, 2008). Whether compliance moderates the degree to which young and older adults demonstrate performance gains after training is an open question, and answering it will require directly measuring the trained process (e.g., strategy use) so as to estimate the degree of compliance and use of the trained processes after training.

The present results indicate that both younger and older adults have the capacity to improve their performance on a demanding WM task when they are given the appropriate cognitive tools to do so. They learned about the efficacy of different verbal encoding strategies and were given limited practice with two effective ones - sentence generation and interactive imagery – on a list-learning task. They were able to apply this knowledge on the RSPAN task when they were told that the trained strategies could be used on a variety of tasks. This finding is noteworthy because other studies suggest that older adults often do not realize that mnemonic strategies can be adapted and used in different situations. For instance, Bottiroli, Dunlosky, Guerini, Cavallini, and Hertzog (2010) found that older adults used a self-testing strategy as often as did young adults when the task more readily afforded its use. However, when the task affordance of this strategy was low, older adults were less likely to use the strategy. Likewise, the use of trained mnemonic strategies does not necessarily occur in different (untrained) task contexts without explicit encouragement to think about how the strategies could be adapted to work in the untrained contexts (Cavallini, Dunlosky, Bottiroli, Hertzog, & Vecchi, 2010).

However, as indicated by reported strategy use in the current experiment, older adults in the training group used the trained strategies on both the WM task and on the paired associate recall task, perhaps because of the surface similarity of the trained and untrained tasks. Even so, results from Bottiroli et al (2010) and Cavallini et al. (2010) suggest that WM improvement after strategy training may be even larger if subjects are explicitly instructed to use their trained strategies on new tasks (such as the WM task). Regarding the larger question of transfer effects, improvements owing to mnemonic strategy training were not apparent in either transfer task. Participants in the training group did not outperform participants in the control group on either paired-associate recall or the SOPT. Participants in the training group reported using the trained strategies more often than did those in the control group on the paired-associate recall task, but this increased strategy use did not benefit them (see Table 4). Further, the training group actually performed more poorly on the SOPT task as compared to the control group, suggesting negative transfer (i.e., attempting to use encoding strategies when they are not useful in the SOPT task context).

Why would the increased use of effective encoding strategies not benefit paired-associate recall, when studies show that associative mnemonics have a positive influence on associative recall (e.g., Richardson, 1998)? One possibility is that the organizational encoding strategies that benefit performance on free recall and WM tasks (e.g., integrating multiple unrelated words into a single sentence or image) are subtly but qualitatively different in their implementation from the mediational strategies needed for paired-associates, in which integration of the two concepts into a single representation is required for optimal associative recall (Richardson, 1998). Experience in using organizational strategies for multiple items may require rapidly finding and adapting a schema or script that loosely ties disparate words in a single context, but that approach may not promote generating a single well-integrated associative mediator binding two words together. Poor implementation of a mediational strategy would lead to high reported strategy use, but also to frequent failures to recall the mediator and the target (see Dunlosky, Hertzog, & Powell-Moman, 2005; Hertzog, Fulton, Mandviwala, & Dunlosky, 2013).

Another possibility (perhaps related to the first) is that participants may have successfully encoded the to-be-remembered items using associative mediators (i.e., images or sentences) and later retrieved these mediators at test. However, they may have failed to decode these mediators at retrieval to recover the target word (given that this process was not trained or practiced in the WM task context). Dunlosky et al. (2005) and Hertzog et al. (2013) found that people sometimes were unable to retrieve the correct items even when they had successfully retrieved the correct mediator for the cue-target word pair, an error that was more common in older adults.

Another possibility is that the trained encoding strategies did benefit performance on the paired-associate task, but the filler task completed by the control group provided experience that also would generalize to paired-associate learning. For instance, the bird learning filler task involved classifying exemplars into categories and may have encouraged associating each bird exemplar (a picture) to its category label. We doubt this possibility can explain the current outcomes, however, given that different kinds of associative processing would likely be required for the two tasks. The bird learning task would rely on a one-to-many mapping (multiple exemplars to each label) involving complex pictures (i.e., bird exemplars) that would not easily afford the use of verbal mediators, which are meant to support paired-associate learning of words and were the focus of strategy training. Note, also, that a final possibility for lack of transfer pertains to a limitation of the current design; namely, participants did not complete the paired-associate recall and SOPT tasks prior to training, so we cannot directly assess gains (or losses) in performance. That is, despite random assignment to groups, perhaps participants in the control group would have performed better on these tasks prior to the intervention. Although we cannot rule out this possibility, given how well the two groups were matched on other demographics, we suspect that it cannot entirely account for the current lack of transfer. In any case, the lack of transfer of the strategy training to paired-associate recall performance suggests that the process-specific strategy training did not have domain-general benefits.

Conclusions

A lesson and practice with effective verbal encoding strategies improved WM performance for both young and older adults, although the age-related WM deficit was not eliminated. Individuals who completed the training used the strategies more often on the WM task and the use of these strategies became more effective for the older adults following training. Lack of transfer effects indicate that increases in WM after training did not arise from domain-general benefits of training but instead were limited to enhanced use of specific processing strategies that were not easily adapted to different performance contexts. Thus, cognitively healthy older adults have the ability to learn (or hone) these strategies and apply them on a demanding WM task.

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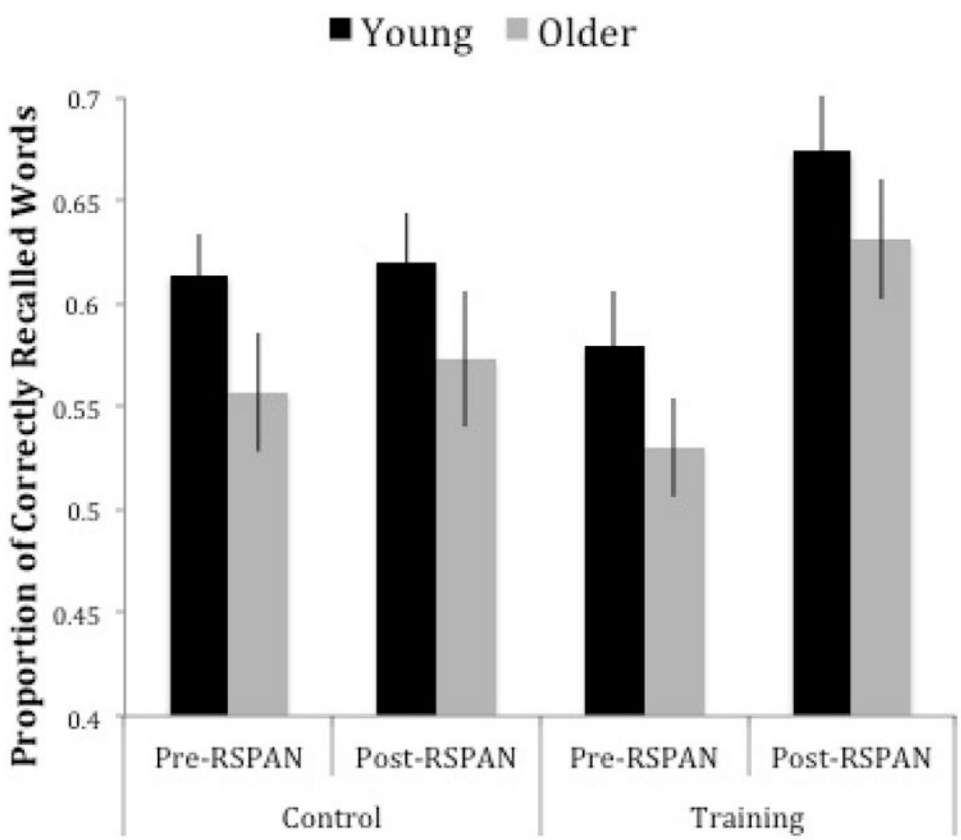

Figure 1.

Reading span performance for young and older adults in the control and training groups. Error bars reflect ±1 standard error of the means.

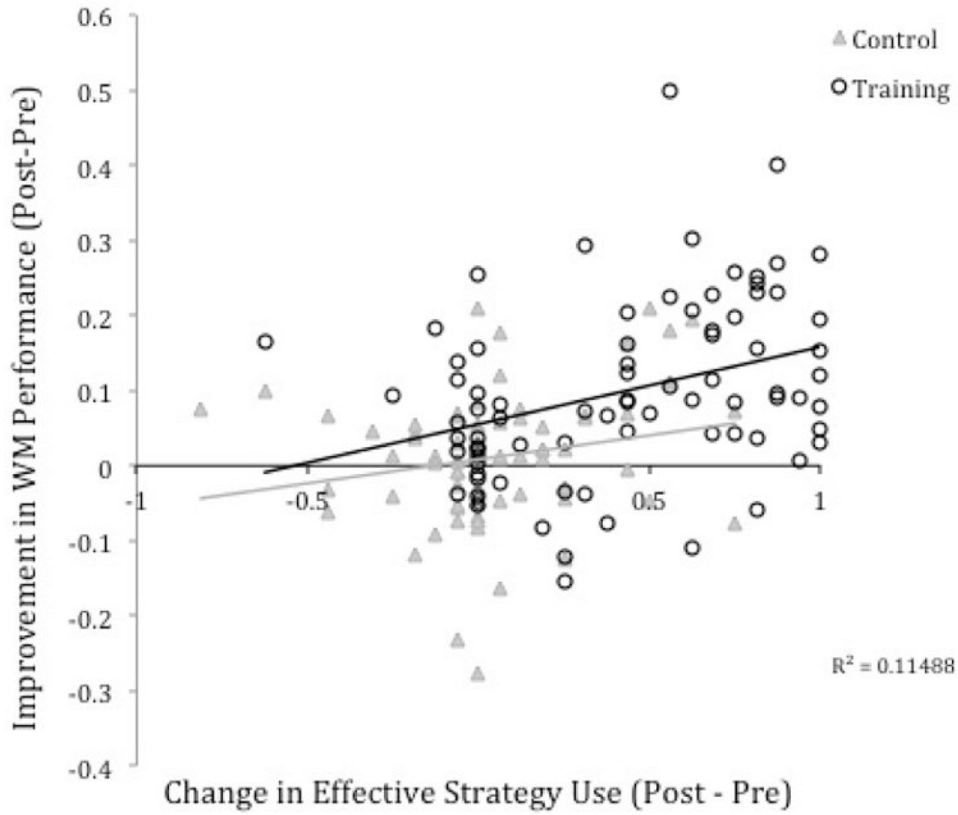

Figure 2.

Scatter plot for the change in effective strategy use and improvement in WM performance for the control and training groups.

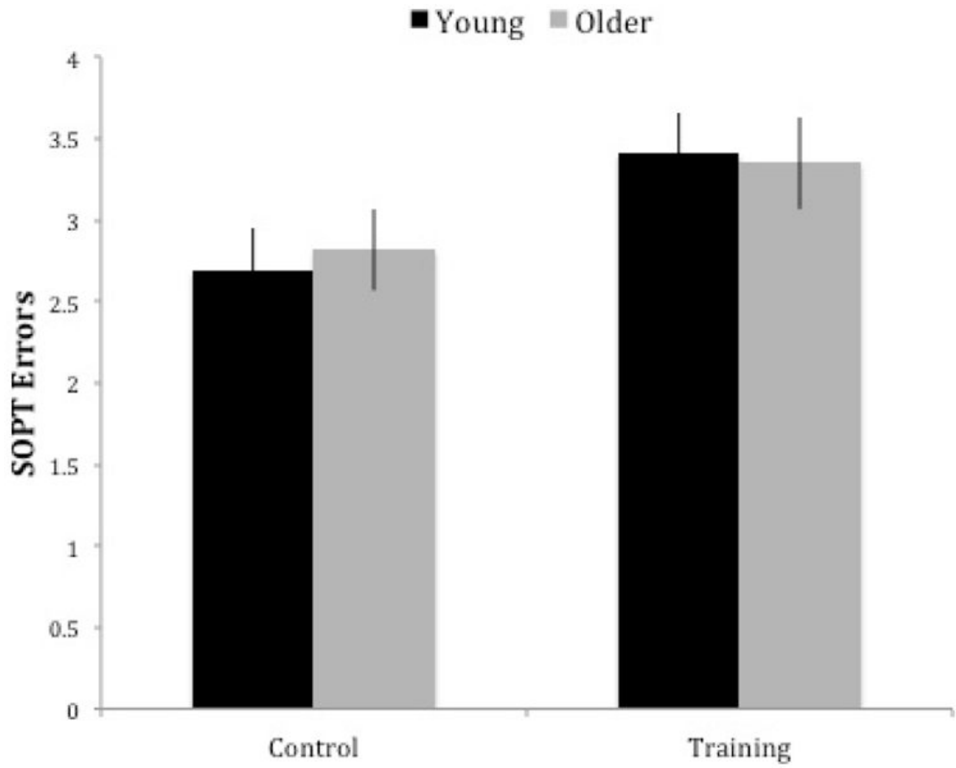

Figure 3.

Mean number of errors that young and older adults reported using on the Self-Ordered Pointing Test. Error bars reflect ±1 standard error of the means.

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Table 1

Demographics

Group	N	Age	Education	Self-Reported Health	Vocabulary	Speed
Young						
Control	38	20.6 (4.3)	12.7 (1.1)	4.3 (.72)	.40 (.13)	18.9 (5.0)
Training	41	21.6 (6.5)	12.3 (0.8)	4.0 (.84)	.42 (.14)	20.3 (4.1)
p		.255	.951	.116	.548	.431
Older						
Control	39	71.7 (7.7)	14.5 (2.2)	3.9 (.73)	.66 (.15)	15.8 (9.4)
Training	39	68.9 (6.9)	14.9 (2.4)	3.7 (.86)	.62 (.16)	14.9 (7.5)
p		.057	.426	.223	.307	.484

Note. N = sample size. Education = average years of education. Self-Reported Health = scores ranged from 1 (poor) to 5 (excellent). Vocabulary = average proportion of correct on Shipley vocabulary test. Speed = average number of items correctly completed on the Letter Comparison test. Standard deviations are reported in parentheses.

Table 2

Proportion of trials that young and older adults in the control and training groups reported using effective strategies on the pre-training and post-training RSPAN tasks.

	Control		Training	
Age group	**Pre-RSPAN**	**Post-RSPAN**	**Pre-RSPAN**	**Post-RSPAN**
Young adults	.30 (.04)	.33 (.05)	.13 (.02)	.59 (.06)
Older adults	.32 (.05)	.36 (.06)	.27 (.05)	.65 (.06)

Note. Standard errors of the means are reported in parentheses.

Table 3

Performance on trials that young and older adults in the control and training groups reported using effective strategies on the pre-training and post-training RSPAN tasks.

	Control		Training	
Age group	**Pre-RSPAN**	**Post-RSPAN**	**Pre-RSPAN**	**Post-RSPAN**
Young adults	.72 (.04)	.72 (.03)	.70 (.04)	.75 (.03)
Older adults	.64 (.04)	.64 (.04)	.52 (.04)	.67 (.03)

Note. Standard errors of the means are reported in parentheses.

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Table 4

Paired-associate recall performance on all trials, proportion of effective strategies reported, and paired-associate recall performance on trials that effective strategies were reported for young and older adults in the control and training groups following training (N = 112).

	Paired Associate Recall		**Proportion of Effective Strategies Reported**		**Paired Associate Recall Given Effective Strategies Used**	
Age group	**Control**	**Training**	**Control**	**Training**	**Control**	**Training**
Young adults	.44 (.05)	.44 (.07)	.45 (.07)	.51 (.08)	.80 (.06)	.63 (.07)
Older adults	.16 (.05)	.25 (.04)	.28 (.06)	.55 (.06)	.53 (.08)	.42 (.06)

Note. Standard errors of the means are reported in parentheses.