Mediator-based encoding strategies in source monitoring in younger and older adults

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Abstract:

Past research has examined the contribution of mediator-based encoding strategies (interactive imagery and sentence generation) to individual (particularly age-related) differences in associative memory exclusively in the paired-associates paradigm. In the present study, we examined young and older adults' mediator-based strategy use on source-monitoring tasks. Participants spontaneously used mediator-based strategies to encode about 30% to 40% of word–source pairs and were able to follow instructions to use the specific mediator-based strategy of interactive imagery; mediator-based strategy use was associated with higher source memory and explained variance in source memory. There were no age-related differences in the patterns of mediator-based strategy production and utilization. Age-related differences in source memory were explained by age-related declines in the ability to bind information in memory (incidental memory for digit–symbol associations) but not by encoding strategy production. Results underscore the importance of assessing encoding strategy use for understanding individual differences in source memory.

Keywords: aging | associative process | cognitive process | human information storage | memory | age differences | imagery | source monitoring | psychology | experimental psychology

Article:

How we process information determines long-term retention, independent of the intent to remember (Craik & Tulving, 1975). People generate mental images, sentences or stories, and group by semantic or subjective criteria to better memorize verbal material (Hertzog, McGuire, & Lineweaver, 1998; Richardson, 1998). Often, we need to remember not only what was learned but also where we learned it, such as remembering where we read something to reread it. Memory for such contextual embedding of information is source memory (Johnson, Hashtroudi, & Lindsay, 1993). The current studies examine encoding strategies for binding item and source information in memory and the extent to which spontaneous encoding strategy production explains differences in source memory, especially related to age.

Encoding Strategies in Source Memory

In a typical source-monitoring task, participants study words in different (usually two) sources, for example speakers, perceptual features (e.g., text types), or spatial positions (Johnson et al., 1993). At test, participants not only have to remember which words they studied but also in which source a word appeared. Thus, source memory depends on the association of a word to its source (Chalfonte & Johnson, 1996). Research on memory for noun pairs suggests that associations are learned best when participants generate a mediator connecting the to-be-associated items (see Richardson, 1998, for a review). A mediator can be an interactive image of the nouns or a verbal connection like a sentence containing both nouns. Mediator-based encoding strategies yield higher memory performance than no encoding strategy or strategies not involving a mediator (e.g., rote repetition) do.

The spontaneous use and effectiveness of mediator-based strategies has been exclusively studied in the paired-associates paradigm, assessing memory for noun pairs. A strategy can be defined as a “procedure or set of procedures for achieving a higher level goal or task” (Lemaire & Reder, 1999, p. 365). Given that the higher level goal in both source monitoring and the paired-associates paradigm is remembering an association, people may use similar strategies in both tasks. Little is known about participants' strategic encoding of item–source associations. Storage of contextual source information is generally assumed to be automatic and nonstrategic and can occur incidentally (e.g., Malmberg & Shiffrin, 2005). However, people may also strategically enhance encoding of item–source associations. Indeed, intentional source-encoding instructions substantially improve source memory (e.g., Chalfonte & Johnson, 1996). Wegesin, Jacobs, Zubin, Ventura, and Stern (2000) found that semantic clustering of words on studied lists also helped adults remember on which list a given word was studied. Even in incidental source encoding, an orienting task probing people to think about the item–source relationship improved source memory (Balardin et al., 2009; Glisky, Rubin, & Davidson, 2001).

Whereas the clustering strategy examined in Wegesin et al. (2000) is specific to semantically related material, the Balardin et al. (2009) and Glisky et al. (2001) studies suggest that people can generate strategies to associate unrelated items to sources. However, it remains unclear how exactly people were processing the item–source relationship in this orienting task. Identifying which strategies people use on source-monitoring tasks and how they affect source memory is crucial for understanding individual differences in and means to improve source memory. A strategy perspective may be particularly relevant for understanding age-related source memory differences.

Do Encoding Strategies Contribute to Age-Related Differences in Source Memory?

Although older adults remember sources and items fairly well, their memory for their combination is poor (Chalfonte & Johnson, 1996), in line with the general finding that age-related differences are more pronounced for associative memory tasks than for item memory tasks (Old & Naveh-Benjamin, 2008). Naveh-Benjamin (2000) proposed that an age-related associative deficit (i.e., a deficit in binding information in memory) underlies age-related differences in episodic memory. However, several studies suggest that encoding strategy deficiencies may also contribute to age-related differences in associative memory, at least in the paired-associates paradigm.

In particular, evidence indicates an age-related production deficiency for mediator-based encoding strategies: Older adults are less likely to spontaneously use these effective strategies when studying noun pairs but can successfully use them if instructed to (Dunlosky & Hertzog, 2001; Hulicka & Grossman, 1967; Naveh-Benjamin, Brav, & Levy, 2007; see Kausler, 1994, for a review). Consequently, age-related differences in associative memory are partially mediated by strategy production; in the Naveh-Benjamin et al. (2007) study, strategy instructions even eliminated them. There is also evidence for age-related utilization deficiencies for mediator-based encoding strategies such that older adults do not benefit as much as young adults (Dunlosky & Hertzog, 1998; Hulicka, Sterns, & Grossman, 1967). Even if older adults improve their associative memory through mediator-based strategies as much as young adults, strategy utilization taxes their available cognitive resources (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005), and older adults forget more mediators or cannot decode them (Dunlosky, Hertzog, & Powell-Moman, 2005). Thus, there are limits to older adults' ability to use mediator-based strategies.

Evidence from the paired-associates paradigm indicating that encoding strategy deficiencies contribute to age-related differences in associative memory complements a broader literature demonstrating that strategy production and utilization influence age-related deficits in various cognitive tasks, including skill acquisition (Touron & Hertzog, 2009) and arithmetic (Lemaire & Arnaud, 2008). However, evidence regarding associative memory thus far exclusively stems from the paired-associates paradigm and may or may not generalize to source memory. Age-related differences in memory are not always related to encoding strategy deficiencies. Recent studies found no age-related differences in encoding strategy production and utilization on working memory tasks (Bailey, Dunlosky, & Hertzog, 2009; Touron, Oransky, Meier, & Hines, 2010), and some studies report age-equivalent encoding strategy use on episodic memory tasks (Lachman & Andreoletti, 2006; Rankin, Karol, & Tuten, 1984). Importantly, age-related production deficiencies in the paired-associates paradigm are easily remedied with strategy instructions or descriptions (Dunlosky & Hertzog, 2001). Researchers have recently begun to examine moderators of age-related production deficiencies (Bottiroli, Dunlosky, Guerini, Cavallini, & Hertzog, 2010; Touron & Hertzog, 2004).

Little is known about age-related encoding strategy differences in source-monitoring. Glisky et al. (2001) and Balardin et al. (2009) found that an orienting task prompting participants to consider the item–source relationship eliminated age-related source-memory differences. However, the relevant comparison condition employed an item-focused orienting task. Hence, it remains unclear whether young and older adults differ in their unguided encoding of item–source associations. Because age-related encoding strategy deficiencies appear malleable, our understanding of their contribution to associative-memory deficits will benefit from examining encoding strategy use in the source-monitoring paradigm.

Overview of the Present Experiments

The present studies explored whether people spontaneously use mediator-based strategies to encode word–source pairs and whether mediator-based strategies improve source memory. We also examined whether age-related encoding strategy deficiencies contribute to age-related differences in source memory by comparing spontaneous strategy production and benefits to source memory between young and older adults. In Experiment 1, we examined the spontaneous use of strategies commonly reported for paired-associates learning and the benefits of imagery instruction in a source-monitoring task with perceptual sources (i.e., text type). In Experiment 2A, we openly explored specific strategies used in source-monitoring tasks, and a tailored strategy catalog was then used in Experiment 2B to examine strategy use in a spatial source-monitoring task that produces a larger age-related deficit.

Experiment 1

In Experiment 1, we examined how frequently young and older adults report encoding strategies common to paired-associates tasks (i.e., imagery, sentence, and repetition) on a perceptual source-monitoring task. Word–source encoding was intentional to maximize associative strategy use. To avoid reactivity of strategy descriptions on spontaneous strategy production (Dunlosky & Hertzog, 2001), we assessed strategy use retroactively. That is, after completing the source-monitoring task, participants indicated the strategy used for each previously studied word–source pair. Experiment 1 further examined whether source memory can be improved through mediator-based strategies. To better establish the causality of strategy use for observed source-memory improvements, we instructed some participants to use interactive imagery. Of particular interest was the contribution of encoding strategies to individual and age-related differences in source memory.

Method

Participants

Forty-four University of North Carolina at Greensboro (UNCG) undergraduates (18–24 years) participated for course credit. Forty older adults (61–75 years) were recruited from the community through newspaper ads and were prescreened for neurological disorders and medications that affect memory. Older adult participants were compensated with $15 (1.5 hr session). Table 1 contains sample characteristics.

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Design and material

The design was a 2 (age group: young vs. old) × 2 (strategy instructions: spontaneous vs. imagery-instructed) factorial with both factors manipulated between participants. As sources, study text type was manipulated with half of the words presented in italic and half presented in bold text type. Participants received either no encoding strategy instructions (hence, strategy use was spontaneous) or instructions to form interactive images for the word–source pairs (22 young and 20 older adults per condition). One hundred one-syllable or two-syllable nouns from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982) were selected with moderate (2.0–5.0 on a 7-point scale) concreteness and imagery ratings (to avoid overestimating strategy production with highly concrete/imaginable words infrequently used in source-monitoring research). Mean ratings for selected nouns were 3.76 (SE = 0.08) for imagery, 3.88 (SE = 0.08) for concreteness, and 59.6 (SE = 4.72) for Kucera-Francis frequency. For each participant, a random 50 words were studied, and the remaining 50 were distractors in the recognition test. The strategy questionnaire used response options from the paired-associates paradigm (Dunlosky & Hertzog, 1998, 2001): "imagery," "sentence," "repetition," "other," and "none/word-only."

Procedure

Participants were tested in age-homogeneous groups of up to six. After signing a consent form, participants completed a computerized demographic questionnaire, a paper-based vocabulary measure (Zachary, 1986), and the paper-based Digit-Symbol Substitution Task (Wechsler, 1981). In the latter task, participants were given a table of pairings of the numbers 1–9 with different symbols and had 90 s to copy the corresponding symbols for a random digit sequence; the total number copied measures basic processing speed. Afterward, participants completed an unannounced cued-recall task for the symbol associated with each number (untimed) to measure incidental associative memory. See Table 1 for mean performance.

Participants completed the computerized source-monitoring task at their own pace. Instructions detailed the memory test assessing both word and text-type memory. For the imagery-instructed condition, information about the positive impact of interactive imagery on associative memory was provided. Examples described images of bold words as wide and big (e.g., a forest with wide trees) and italic words as slanted and skinny (e.g., a forest with skinny, slanted trees). Participants then practiced generating their own images. They were encouraged to come up with an interactive image for each word–source pair. In the study phase, 50 words appeared centered, one at a time. For each participant, a random half appeared in italic, whereas the other half appeared in bold text type with the restriction of no more than three consecutive presentations in the same text type. Word–text type pairs were presented for 4 s, separated by a 500 ms centered-cross fixation screen.

Following study, participants verified simple arithmetic equations for 1.5 min and then read instructions for the memory test. At test, each word (studied and unstudied, randomly ordered) appeared centered on the screen in regular text type. Participants first decided whether a word was old or new by mouse-clicking a response field underneath the test word. Only if the response was “old” were participants next asked to indicate what text type they studied the word in by clicking a response field. If the response to a test word was “new,” text type was not asked about and the next test word was immediately presented. Assignment of response options to the right-hand and left-hand field was counterbalanced. After clicking, the response field turned red, and participants could either change their answer or click a “RECORD” field on the bottom. Following a source response or a “new” response, the next test word appeared.

After the test phase, instructions for the retrospective item-level strategy questionnaire appeared. For participants in the spontaneous condition, this was the first time encoding strategies were mentioned. Interactive imagery (see examples earlier), sentence generation (e.g., verbally describing a bold word as modern and an italic word as antique), and rote repetition (e.g., mentally repeating the word and text type) were described. Instructions emphasized associative encoding strategies involving both the word and its source and emphasized that “other” should only be chosen for a different strategy accomplishing this. Any strategies just involving the to-be-studied words (without source) and the use of no encoding strategy were to be reported as “none/word-only.” Participants were ensured that choosing the same strategy for each word–text type pair, including “none/word-only,” was fine, as was reporting many different strategies. The 50 studied word–text type pairs were then presented again, in a new random order. Each word was presented centered on the screen in the studied text type, with response fields labeled with the five strategy response options and a RECORD field on the bottom. Participants could indicate having used more than one strategy on a given pair by selecting multiple strategy fields. Finally, participants reported their experience and beliefs about the task and were then debriefed.

Results and Discussion

Overall source memory

We used the conditional source-identification measure (CSIM) because it is independent of item identification under most circumstances (cf. Murnane & Bayen, 1996). This index is calculated as the proportion of correct source attributions for all recognized items from each source (e.g., bold words correctly classified as bold out of all recognized bold words). Single-source CSIMs for the two text types were then averaged to represent overall source memory (average conditional source-identification measure; ACSIM); see Table 2 for mean scores. A 2 (age group) × 2 (strategy instructions) analysis of variance (ANOVA) yielded a significant main effect of age group, $F(1, 80) = 5.09$, $p = .027$, η p2 = .06, indicating worse source memory in older adults. There was also a main effect of strategy instructions, $F(1, 80) = 9.47$, $p = .003$, η p2 = .11, with higher source memory in the imagery-instructed than in the spontaneous condition. That is, instructions to use a mediator-based strategy that improves memory for noun pairs also significantly improved source memory. The interaction was not significant ($F < 1$); young and older adults equally improved their source memory with imagery instructions. Imagery instructions did not reduce age-related differences in source memory, contrary to a production deficiency hypothesis.

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Strategy use

Table 2 displays the mean proportion of trials on which each strategy was used by itself or combined with others. Combination of encoding strategies was rare, with the exception that young adults in the imagery-instructed condition frequently combined interactive imagery and sentence generation ($M = .12$, $SE = .04$), more so than did older adults ($M = .02$, $SE = .02$), $t(40) = 2.247$, $p = .030$, $d = 0.71$. There was also an age-related difference in the number of different strategies used, with older adults, on average, using fewer different strategies across the task ($M = 2.03$, $SE = 0.15$) than did young adults ($M = 2.59$, $SE = 0.15$), $F(1, 80) = 7.25$, $p = .009$, $\eta_p^2 = .08$. For the present analyses, we grouped interactive imagery and sentence generation as mediator-based strategies and grouped rote repetition, word-only strategies, and no strategies as no-mediator strategies. [1]"Other" strategies were excluded as their nature is ambiguous. We counted any use of interactive imagery or sentence generation as instances of mediator-based strategy use, even if combined with repetition or other strategies. The mean proportions of trials on which mediator-based strategies were used were submitted to a 2 (age group) × 2 (strategy instructions) ANOVA (see Figure 1). There was a main effect of strategy instructions, $F(1, 80) = 16.26$, $p < .001$, $\eta_p^2 = .17$, with a higher use of mediator-based encoding strategies after imagery instructions. The effect of age group was not significant, $F(1, 80) = 2.06$, $p = .155$, $\eta_p^2 = .03$, nor was the interaction ($F < 1$). Thus, even though young adults used more strategies altogether, young and older adults spontaneously used mediator-based encoding strategies equally often and complied similarly with instructions to use interactive imagery. It is noteworthy that the imagery instructions increased mediator-based strategy use overall (imagery, sentence, or their combination) rather than just increasing imagery; presumably, some compliant participants preferred verbal mediators. Considering mediator-based strategy use overall, compliance with strategy instructions (58% in older adults, 68% in young adults) was comparable with instructed conditions in the paired-associates paradigm (Dunlosky & Hertzog, 1998). Numerically, older adults used mediator-based strategies on average for about 10% fewer trials in both conditions. Because mediator-based strategy use was variable, this constitutes a small effect ($d = 0.2$). Although this age-related difference may reach significance in a large sample ($n = 620$ for power = .80), age-related differences in mediator-based strategy production are at most small and thus unlikely to account for age-related differences in source memory.

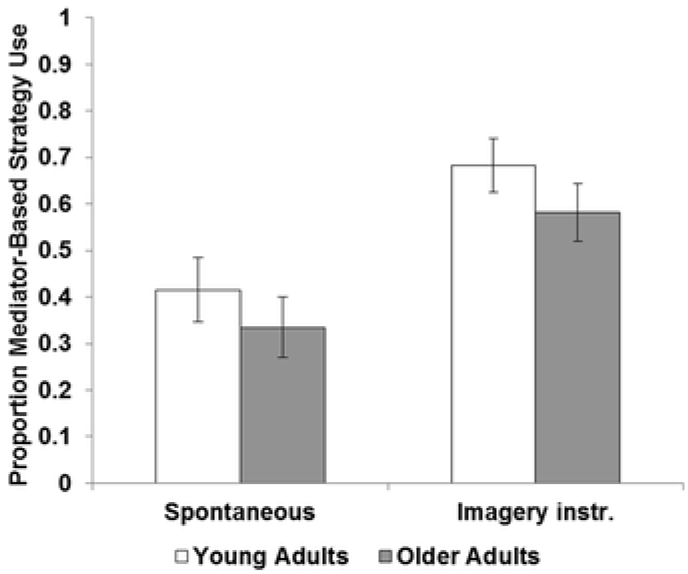

Figure 1. Mean proportion of mediator-based strategy (interactive imagery and sentence generation) use by age group and strategy instructions in Experiment 1. Error bars represent standard errors. Instr. = instruction.

Source memory by strategy

Next, we compared source memory under mediator-based strategies (interactive imagery and sentence generation) to source memory under no-mediator strategies (rote repetition, word-only, and no strategy) to examine the effectiveness of mediator-based encoding strategies for source memory. “Other” strategies were not analyzed due to their ambiguous nature. Strategies were grouped rather than examined individually because analyses by individual strategies would cause substantial dropout because few participants used all strategies (see Bailey et al., 2009; Touron et al., 2010, for similar approaches). Our main interest for the current study was the effect of mediator-based encoding on source memory rather than differences between individual strategies. Mean ACSIM 2 scores (see Figure 2) were submitted to a 2 (strategy) × 2 (age group) × 2 (strategy instructions) mixed ANOVA with strategy as a within-participants factor. This analysis excluded participants (24%) who did not provide data for both strategy groups, but patterns were consistent with means based on all data. The age-related source memory deficit persisted even if young and older adults used the same strategy, indicated by a main effect of age group, $F(1, 60) = 4.99$, $p = .029$, $\eta_p^2 = .08$. Strategy instructions did not have a significant main effect ($F < 1$). A main effect of strategy, $F(1, 60) = 39.05$, $p < .001$, $\eta_p^2 = .40$, indicated higher source memory with mediator-based strategies, compared with no-mediator strategies. There was a trend for an interaction of strategy and strategy instructions, $F(1, 60) = 3.94$, $p = .052$, $\eta_p^2 = .06$. Mediator-based strategies yielded better source memory when generated both spontaneously or after imagery instructions, but this strategy effect was larger after imagery instructions ($d = 0.72$ for spontaneous, $d = 1.31$ for imagery instructed). No other interactions were significant (Fs ≤ 1.41). The absence of interactions involving age group indicates that older adults' source memory improved with mediator-based strategies as much as young adults', suggesting no age-related differences in mediator-based strategy utilization. However, age-related differences in source memory persisted even when young and older adults were using the same strategy type.

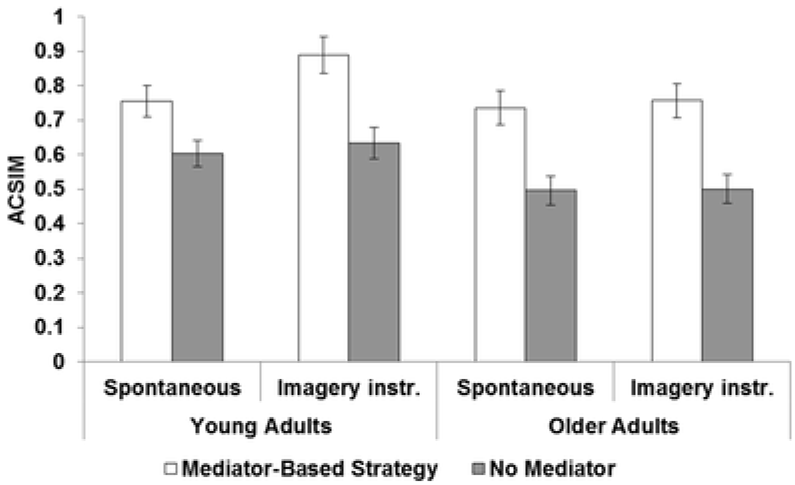

Figure 2. Mean source memory (average conditional source-identification measure; ACSIM) by strategy type, age group, and strategy instructions in Experiment 1. Error bars represent standard errors. Instr. = instruction.

Individual differences in source memory

To identify predictors of individual differences in source memory (ACSIM) we conducted a stepwise regression with age group, proportion of mediator-based strategies, number of strategies used, vocabulary, processing speed (Digit-Symbol completion), and incidental associative memory (Digit-Symbol memory) as predictors. This analysis included all participants. Table 3 displays bivariate correlations of these measures. The stepwise procedure yielded a final model that explained 15.1% of the source memory variance, $F(2, 81) = 7.21$, $MSE = .02$, $p = .001$, with two predictors (entered as listed): (1) mediator-based strategy use ($\beta = .26$, $p = .018$) and (2) incidental associative memory ($\beta = .24$, $p = .030$). Age group on its own was a significant predictor of source memory ($\beta = -.23$, $p = .035$). Entering mediator-based strategy use slightly reduced the regression coefficient of age group ($\beta = -.19$, $p = .074$), but Sobel's test did not suggest that strategy use mediated age-related differences in source memory ($z = -1.22$, $SE = .01$, $p = .223$). Notably, observed age-related differences in the number of strategies used were not significantly correlated with source memory. Entering incidental associative memory as an additional predictor reduced the effect of age group ($\beta = -.14$, $p = .202$). Sobel's test indicated that incidental associative memory significantly mediated the effect of age group on source memory ($z = -2.17$, $SE = .01$, $p = .030$). That is, age differences in source memory were mediated by an age-related deficit in binding information in memory and not by encoding strategy production, supporting the associative-deficit theory (Naveh-Benjamin, 2000).

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Overview of Experiments 2A and 2B

The results from Experiment 1 show that individual differences in source memory were partially explained by mediator-based strategy use. However, encoding strategies do not seem to explain the age-related source-memory deficit; this is true for the use of more effective mediator-based strategies in which no age-related differences occurred as well as for other aspects of strategy use (e.g., number of strategies used) in which age-related differences did occur. Given the importance of this finding, we strove to replicate and extend it in a different source-monitoring task producing a larger age-related deficit. A further goal was to more precisely capture strategies used in source monitoring. Overall, Experiment 1 indicated that strategies commonly used in the paired-associates paradigm reflected strategy use in a source-monitoring task well, but reports of using “other” strategies amounted to averages of up to 17% of the word–source pairs. Therefore, Experiment 2A explored encoding strategies in source-monitoring tasks with open strategy reports to tailor a strategy catalog for this paradigm. Experiment 2B examined the role of encoding strategies for individual and age-related differences in source memory in a spatial source-monitoring paradigm known to produce larger age-related source-memory differences than the perceptual source-monitoring paradigm used in Experiment 1 (cf. Old & Naveh-Benjamin, 2008) and further extended Experiment 1 by comparing concurrent and retrospective strategy reports to ensure the validity of the retrospective reports.

Experiment 2A

To get a better sense of the types of strategies used in source-monitoring tasks, we collected open strategy reports from young adults. Participants described anything they did to study a given word–source pair immediately after study presentation of each pair. Hence, when strategy reports were made, information on the strategic processing should still be accessible in working memory, fostering report reliability (Ericsson & Simon, 1980) and removing any influence of provided options. We tested some participants with spatial position sources and tested some participants with the text-type sources from Experiment 1 to compare encoding strategies for different source-monitoring tasks.

Method

Participants

Forty UNCG undergraduates (mean age = 19.08 years, range 18–31) participated for course credit. Given the commonalities between young and older adults' strategy use in Experiment 1, including no differences in the frequency of “other” reports, we tested only young adults, who should be more comfortable typing strategy descriptions and should have the most comprehensive strategy repertoire (cf. Lemaire, 2010).

Design and material

A random half of the participants were tested in the same paradigm as Experiment 1, with italic versus bold text type as the source manipulation (text-type condition), whereas the other half were tested in a paradigm in which the study words appeared on the top or bottom of the screen as the source manipulation (position condition). One hundred words were selected from the Toronto Word Pool (Friendly et al., 1982). Spontaneous strategy use was encouraged (in order to maximize information available in the open reports) by selecting half of the words to be very high in imagery and concreteness (6.0 and above on 7-point Likert scales), whereas the other half had moderate ratings (2.0–5.0, as in Experiment 1). For each participant, 60 words were randomly selected for study with the restriction that half were highly concrete and imaginable. A random 15 words of each concreteness/imagery level were presented in each source.

Procedure

The procedure was identical to the source-monitoring task in Experiment 1 with the following exceptions. For participants in the position condition, all study words were presented in regular text type centered on either the top or bottom of the screen. To keep the study phase more akin to a typical source-monitoring study phase, each participant was only probed for encoding strategy on 20 of the 60 studied word–source pairs, selected randomly with the restriction that for each source, five words of high and five words of moderate concreteness/imagery were probed. For probed word–source pairs, after the 4 s presentation time, a screen asked participants to describe anything done to study the last word–source pair. Participants typed responses with unlimited report length and the option to make corrections. Then, the next pair was immediately presented.

Strategy coding

Both authors independently coded the open strategy reports with a coding catalog based on the strategy questionnaire used in Experiment 1, supplemented by descriptions of “other” strategies participants provided in a posttask questionnaire. Examination of these descriptions suggested that some participants used a story–cluster strategy in which the words presented in one source were related to each other via a story or some meaning-based grouping criterion. We also defined a special repetition category for the case in which words of one source are repeated together without meaning-based connections: repetition cluster. Hence, open strategy reports were coded with the following options: (a) imagery, (b) sentence, (c) story–cluster, (d) repetition, (e) repetition cluster, (f) other, and (g) none. Any described encoding activity was to be coded as “other,” but responses indicating that nothing was done for memorization (e.g., “I didn't do anything,” or “I yawned.”) were coded “none.” We coded whether the source (text type or position) was included in the strategy. Coding consistency was satisfactory, with 80% agreement on strategy and 82% agreement on source inclusion. Inconsistencies were resolved via discussion. One participant in the text-type condition was excluded because he or she gave insufficient strategy descriptions.

Results and Discussion

For each participant, we calculated the proportion use for each strategy on the 20 probed word–source pairs. Given the focus on associative strategies in the current study, we collapsed across the different word-only strategies. Because “repetition cluster” was rare (average use of 2.3%) and was similar to repeating word and source, we combined these. Mean proportions are presented in Table 4 with the number of participants who used each strategy at least once. On average, strategies included the source on about 60% of probed trials. Further, the strategies assessed in Experiment 1, particularly sentence and repetition, comprised the majority of associative (word + source) strategies used. Notably, the “imagery” coding was rarely assigned (for only one participant in the text-type condition). For this coding, we required that participants explicitly mentioned an accompanying image. It is plausible that many reports coded as sentence actually involved (unmentioned) mental picturing. Further, comparison of the text-type condition with Experiment 1 suggests somewhat lower use of mediator-based strategies; note that these reports only reflect strategy use on a third of the study list.

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To compare strategy use between the two sources, we submitted proportions of strategy use to a Source Condition (text type vs. position) × Strategy (imagery vs. sentence vs. story vs. repetition vs. other vs. none) mixed ANOVA. Word-only strategies were not included to eliminate the dependency between cells. There was no main effect of source type ($F < 1$) but a significant main effect of strategy, $F(5, 185) = 3.64$, $p = .004$, $\eta_p^2 = .09$, qualified by a significant interaction with source condition, $F(5, 185) = 3.08$, $p = .011$, $\eta_p^2 = .08$. Follow-up independent t tests revealed that the two source conditions did not differ in the mean proportions of imagery, story–cluster, other, and none use (ts ≤ 1.48), but sentence use was significantly higher in the position condition, $t(37) = 2.05$, $p = .047$, $d = 0.68$, and repetition use was significantly higher in the text-type condition, $t(37) = 2.39$, $p = .022$, $d = 0.76$. That is, even though the same strategies were used in both source tasks, there were source-related differences in how frequently particular strategies were used.

Up to 15% of reports of strategic encoding of the word and the source were coded as “other.” We each examined these responses more closely to identify common strategies reported by multiple participants. Many of the strategies appeared idiosyncratic, but we were able to assign labels and identify more than one person using a few additional strategies. These were making physical gestures (e.g., pointing up or tapping desk; 36% of strategies coded other word + source from one participant in the text type and four participants in the position condition), staring at the word–source combination (7%; three position participants), noticing physical resemblances (e.g., noticing how italicized letters make the ys in cherry look like cherry stems; 6%; one position and one text type participant), and memorizing patterns (e.g., “italic, italic, bold, italic”; 3%; one text type and one position participant). These results suggest that physical gesturing might be somewhat frequently used, especially in the position condition and, thus, should be added to the strategy questionnaire.

Experiment 2B

Experiment 2A revealed that spontaneous strategy use differs across source-monitoring tasks. Spatial sources are known to produce larger age-related source memory differences (Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995). Hence, the purpose of Experiment 2B was to determine whether the findings of no strategy deficiencies in older adults generalize to a spatial source-monitoring task. Experiment 2B further used a modified strategy questionnaire, adding the “story–cluster” and the “gesture” strategies identified in Experiment 2A; strategy options tailored for the source-monitoring paradigm should allow more precise assessment. Lastly, Experiment 2B collected concurrent (i.e., immediately after each word–source encoding) strategy reports from some participants in addition to the retrospective reports, to validate the retrospective strategy reports and ensure that source memory by strategy estimates are not inflated by source memory affecting strategy reports.

Method

Participants

Sixty UNCG undergraduates (18–25 years) and 51 older adults (61–78 years) were recruited and compensated as in Experiment 1. Table 1 contains sample characteristics.

Design and material

The design was a 2 (age group: young vs. old) × 2 (strategy-report condition: concurrent + retrospective vs. retrospective-only) factorial with both factors manipulated between participants. As sources, the screen position of the studied words was manipulated with half of the words presented (horizontally centered) on the top and the other half on the bottom of the screen. Participants in the concurrent + retrospective condition (30 young and 25 older adults) made a strategy report immediately after studying each word–position pair as well as retrospectively upon completion of the source-monitoring test. Participants in the retrospective-only condition (30 young and 26 older adults) only gave retrospective reports. All strategy reports used a modified questionnaire with the following options: (a) imagery, (b) sentence, (c) story–cluster, (d) repetition, (e) gesture, (f) other, and (g) none/word-only. To improve participant understanding, we used more descriptive labels (e.g., “sentence” was labeled “Connecting the MEANING of the word and its position”). We asked participants to pick one response that best described what they did; that is, participants could not report combining strategies, which was rare in the spontaneous conditions of Experiment 1. The word pool from Experiment 1 was used; to increase observances of strategy use, 60 words were randomly selected for study, and the remaining 40 were distractors.

Procedure

The procedure was identical to Experiment 1 with the following changes. Strategy use was always spontaneous (i.e., no strategy instructions). Further, for participants in the concurrent + retrospective condition, after participants studied each word–position combination for 4 s, a screen asked participants to indicate what (if any) strategy they had used. The seven strategy options were listed with their descriptive label, and participants responded by pressing a number key; options were explained with examples before the study phase. Examples for imagery were picturing words as flying or laying on the ground and for sentence were to describe top words as superior and bottom words as inferior. Strategy reports were self-paced, but participants were asked to respond as quickly as possible. After responding, a centered fixation cross was shown for 500 ms before the next word appeared. In the retrospective strategy questionnaire, a square indicated the study screen, and the words appeared in the square's top or bottom, depending on study position, with all response options listed beneath this. Before the retrospective strategy questionnaire (immediately after the source-monitoring test), all strategy response options were explained with examples (in the retrospective-only condition, this was the first mention of strategies). All participants were asked to remember what (if any) strategy they used to study each word–position pair.

Results and Discussion

Overall source memory

Mean ACSIM scores (see Table 5) were submitted to a 2 (age group) × 2 (strategy-report condition) ANOVA. Older adults had poorer memory for positions than did young adults, $F(1, 104) = 25.79$, $p < .001$, $\eta_p^2 = .19$. A main effect of strategy-report condition, $F(1, 104) = 36.92$, $p < .001$, $\eta_p^2 = .26$, confirmed higher source memory in the concurrent + retrospective condition. This condition effect did not interact with age ($F < 1$). That is, making concurrent strategy reports had reactive effects on source memory, perhaps due to increased strategy use (assessed next) or to the extra study time 3 these reports inevitably provided.

Table 5 is omitted from this formatted document.

Strategy use

Mean proportions of use for each strategy are reported in Table 5. The concurrent + retrospective strategy-report condition allows assessment of the validity of retrospective strategy reports in this paradigm. For each participant, we computed the mean proportion of word–position pairs for which the concurrent and retrospective strategy report were consistent. Reports were moderately consistent (young: $M = .61$, $SE = .04$; old: $M = .61$, $SE = .05$), with no age-related differences, $t(53) < 1$, suggesting moderate validity of retrospective reports for both age groups (cf. Dunlosky & Hertzog, 2001).

The added strategies “story–cluster” and “gesture” were rarely endorsed, but the broader strategy catalog dropped “other” reports below 10%, comparable with levels seen in the paired-associates paradigm (Bailey et al., 2009; Dunlosky & Hertzog, 1998, 2001). Of most interest were again proportions of mediator-based strategy use, shown in Figure 3. 4 A 2 (age group) × 2 (time of report: concurrent vs. retrospective) mixed ANOVA in the concurrent + retrospective condition revealed no significant effect of age group ($F < 1$). That is, despite the large age-related deficit in source memory in this paradigm, there was again no evidence for a production deficiency in older adults, with both age groups using mediator-based strategies on about 40% of the word–position pairs. Further, there was neither a significant effect of time of report nor an interaction (both $F < 1$), again underscoring the validity of the retrospective reports for both age groups. To compare retrospective reports from the two report conditions, we conducted a 2 (age group) × 2 (strategy-report condition) ANOVA on the retrospectively reported proportion of mediator-based strategy use. Although mediator-based strategy use was about 10% higher in the concurrent + retrospective condition, the condition effect was not significant given the variability of strategy use, $F(1, 107) = 1.90$, $p = .171$, $\eta_p^2 = .02$. There was still no evidence for a main-effect of age group or an interaction in this combined sample ($F < 1$). Providing strategy descriptions before encoding as is necessary for concurrent strategy reports has previously been found to selectively boost older adults' mediator-based strategy use in the paired-associates paradigm (Dunlosky & Hertzog, 2001). However, in the present spatial source-monitoring task, with no age-related differences in mediator-based strategy production, even in the retrospective-only condition, concurrent strategy reports did not affect older adults' strategy production. If anything, a very slight increase in mediator-based strategy use in the concurrent + retrospective condition was age-equivalent. This implies that the increase in source memory with concurrent reports is caused by the extra study time inevitably provided. Further, there was no evidence that older adults' are less likely to spontaneously use mediator-based strategies on a source-monitoring task, replicating Experiment 1.

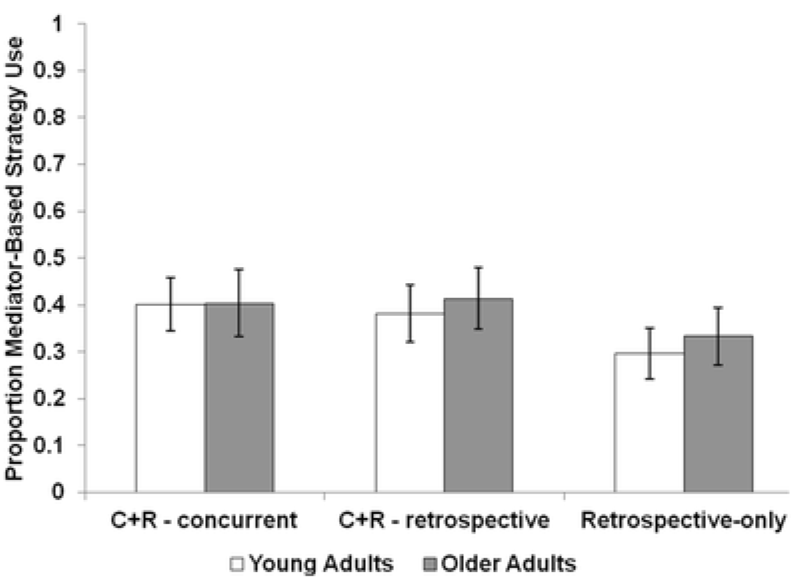

Figure 3. Mean proportion of mediator-based strategy (interactive imagery and sentence generation) use by age group and strategy-report condition in Experiment 2B. Error bars

represent standard errors. C+R–concurrent = based on concurrent reports from the concurrent + retrospective strategy report condition; C+R–retrospective = based on retrospective reports from the concurrent + retrospective strategy report condition.

Lastly, we examined age-related differences in the number of different strategies used across the task. In the concurrent + retrospective strategy-report condition, a 2 (age group) × 2 (time of report) ANOVA yielded a main effect of time of report, $F(1, 53) = 15.68$, $p < .001$, $\eta_p^2 = .23$, with participants reporting a greater number of different strategies concurrently than retrospectively. Unlike Experiment 1, age groups did not differ in the average number of strategies used, nor was there an interaction of age group and time of report (Fs ≤ 1.71; young concurrent: $M = 3.40$, $SE = 0.32$; young retrospective: $M = 2.37$, $SE = 0.27$; old concurrent: $M = 3.20$, $SE = 0.35$; old retrospective: $M = 2.68$, $SE = 0.30$). For the retrospective-only condition, there was a trending age-related difference in the number of strategies used, $t(54) = 1.70$, $p = .096$, $d = 0.45$, with older adults using slightly fewer different strategies across the task ($M = 2.42$, $SE = 0.28$) than young adults ($M = 3.13$, $SE = 0.30$). Concurrent strategy reports may have eliminated age-related differences in the average number of strategies used because of the early provision of strategy options.

Source memory by strategy

Figure 4 plots mean ACSIM by type of strategy. In the concurrent + retrospective condition, we conducted a 2 (age group) × 2 (time of report) × 2 (type of strategy: mediator-based vs. no-mediator) mixed ANOVA on ACSIM (see footnote 2). Again, there was dropout (39%) from participants who did not use both types of strategies, but the mean patterns based on all available data were consistent with those from the mixed ANOVA. There was a significant main effect of age group, $F(1, 32) = 10.47$, $p = .003$, $\eta_p^2 = .25$, indicating poorer source memory in older adults even when using the same strategy as young adults. Strategy significantly impacted source memory, $F(1, 31) = 42.82$, $p < .001$, $\eta_p^2 = .57$, with source memory higher under mediator-based than under no-mediator strategies. All other effects were not significant (Fs < 1), indicating that this strategy effect was stable across age groups and time of report. As in Experiment 1, this suggests that older adults can use mediator-based strategies to improve their source memory as efficiently as young adults, opposing a utilization deficiency hypothesis. The absence of effects involving time of report suggests that retrospective strategy reports accurately reflect the impact of encoding strategies in both age groups.

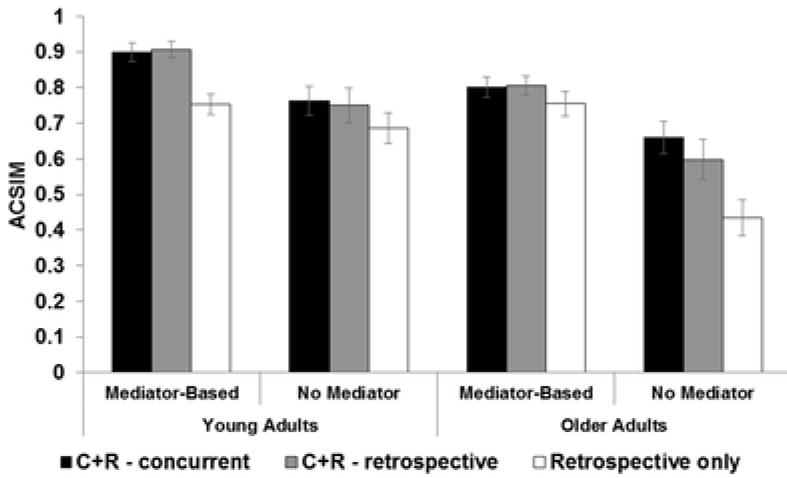

Figure 4. Mean source memory (average conditional source-identification measure; ACSIM) by strategy type, age group, and strategy-report condition in Experiment 1. Error bars represent standard errors. C+R–concurrent = based on concurrent reports from the concurrent + retrospective strategy report condition; C+R–retrospective = based on retrospective reports from the concurrent + retrospective strategy report condition.

A 2 (age group) × 2 (type of strategy) mixed ANOVA was conducted on ACSIM in the retrospective-only condition (29% dropout, similar mean patterns in all data). A main effect of age, $F(1, 38) = 7.30$, $p = .010$, $\eta_p^2 = .16$, indicated poorer source memory in older adults after controlling for encoding strategy. Mediator-based strategies were again associated with higher source memory, $F(1, 38) = 29.82$, $p < .001$, $\eta_p^2 = .44$. However, this strategy effect interacted with age group, $F(1, 38) = 12.80$, $p = .001$, $\eta_p^2 = .25$. Source memory was higher under mediator-based strategies for older adults, $t(16) = 5.42$, $p < .001$, $d = 1.33$. The same pattern emerged in young adults, but the difference was not significant, $t(22) = 1.57$, $p = .131$, $d = 0.33$. This outcome again opposes a utilization deficiency hypothesis; if anything, older adults more effectively used mediators to improve their source memory.

Individual differences in source memory

We again conducted a stepwise regression with age group, proportion of mediator-based strategy use (averaged for the two reports in the concurrent + retrospective condition), number of strategies used (averaged for the two reports in the concurrent + retrospective condition), vocabulary, processing speed (Digit-Symbol completion), and incidental associative memory (Digit-Symbol memory) as potential predictors of source memory (ACSIM). This analysis included all participants excepting one young adult who was noncompliant on the processing-speed task. Table 3 presents bivariate correlations of these measures. The final model explained 24.5% of the variance in source memory, $F(2, 107) = 17.35$, $MSE = .02$, $p < .001$, with the following two predictors (entered as listed): (1) age group ($\beta = -.41$, $p < .001$) and (2) mediator-based strategy use ($\beta = .29$, $p = .001$). On its own, age group predicted 15.5% of variance in source memory, and its regression weight ($\beta = -.39$, $p < .001$) was not reduced when mediator-based strategy use was entered into the model; that is, strategy use did not mediate age-related differences in source memory (Sobel's $z = 0.44$, $SE = .01$, $p = .663$). However, entering incidental associative memory, identified as a mediator of age-related source memory differences in Experiment 1, reduced the age group's regression weight ($\beta = -.34$, $p < .001$), and Sobel's test indicated significant partial mediation ($z = -2.45$, $SE = .01$, $p = .01$). Whereas in Experiment 1 incidental associative memory fully mediated the effect of age group on source memory, mediation was only partial in this spatial source-monitoring task; age group significantly predicted source memory over and above incidental associative memory and was thus the more powerful predictor, added in the stepwise procedure.

General Discussion

Both experiments suggest that adults spontaneously use mediator-based encoding strategies (i.e., interactive imagery and sentence generation) on source-monitoring tasks. Instructions to use interactive imagery increased mediator-based strategy use, indicating that even participants not spontaneously using these strategies frequently were able to implement them when instructed. Source memory was generally higher with mediator-based strategies, compared with no-mediator strategies (rote repetition, word-only, and none). Instructions to use imagery significantly improved source memory, suggesting that mediator-based strategies are beneficial even for those who do not spontaneously use them. The strategy benefit to source memory was also evident based on concurrent strategy reports, suggesting that source memory did not inflate retrospective strategy judgments.

Encoding strategies commonly reported in the paired-associates paradigm (interactive imagery, sentence, and rote repetition) appear to also be the primary strategies used on source-monitoring tasks, as evidenced by endorsement of these strategies from checklists (Experiments 1 and 2B) as well as by open reports (Experiment 2A). The finding that similar strategies are used in the two paradigms befits the common higher goal of the two tasks (i.e., forming associations). Open reports further revealed two source-monitoring specific strategies, one being the meaning-based connection of words presented in the same source through a story or grouping, the other being gesturing out the source. However, reported use of such strategies was fairly rare.

Overall, older adults were as likely as young adults to use effective mediator-based strategies to encode the word–source pairs, even if no strategy descriptions were provided before encoding and strategy production was thus truly spontaneous (cf. Dunlosky & Hertzog, 2001). That is, there was no evidence that a production deficiency contributed to the age-related source-memory deficit. This finding contrasts with two prior studies in which an associative orienting task eliminated age-related differences in source memory (Balardin et al., 2009; Glisky et al., 2001). However, in both studies, source learning was incidental and comparison conditions (across experiments for Glisky et al.) employed an orienting task focusing on the item only. Even though young adults may be better able to process contextual elements while performing an item-focused orienting task, our studies suggest that there are no age-related differences in the qualitative processing of context features in relation to the item when encoding is unguided and source learning is intentional. Glisky et al. (2001) further only found benefits of an associative orienting instruction in older adults low in frontal functioning. We examined a community-based sample of healthy, high-functioning older adults, as do many cognitive aging studies. Despite this, we still found large age-related source memory differences (at least with spatial sources), in the absence of strategy deficiencies. Further research should examine the role of frontal functioning for mediator-based strategy production.

The finding of no age-related production deficiencies is consistent with recent findings comparing adults' strategy use on working memory tasks (Bailey et al., 2009; Touron et al., 2010) but contrasts with several studies using the paired-associates paradigm (Dunlosky & Hertzog, 2001; Hulicka & Grossman, 1967; Naveh-Benjamin et al., 2007). Notably, the spatial source-memory deficit is comparable with the age-related deficit in noun-pair memory (cf. Old & Naveh-Benjamin, 2008), and these studies had similarly high-functioning older adult samples. Task paradigms differ in how much they afford mediator-based strategy use, and older adults might be particularly sensitive to a tasks' strategy affordance (Bottiroli et al., 2010; Touron & Hertzog, 2004). The source-monitoring paradigm is characterized by a many-to-one mapping; that is, many items appear in a limited number of sources, often just two, as in our experiments (cf. Johnson et al., 1993). This is in stark contrast to the paired-associates paradigm, in which two new items are associated on each trial. The repetition of sources throughout the task might facilitate mediator-based strategy use because once a mediator has been developed for a source it can be reused (e.g., picturing all italic words as small and slanted). Future research should determine moderators of age-related production deficiencies for mediator-based strategies.

There was also no evidence for any strategy utilization deficiencies. Older adults improved their source memory by using mediator-based strategies as much as young adults. Thus, older adults' source-memory performance appears to be as plastic as young adults' (see also Balardin et al., 2009; Glisky et al., 2001). Aging is sometimes associated with reduced memory plasticity, for example age differences magnify after instruction in the method of loci (Kliegl, Smith, & Baltes, 1990; Verhaeghen & Marcoen, 1996). However, older adults' ability to use interactive imagery and sentence generation appears to be preserved (Bailey et al., 2009; Dunlosky & Hertzog, 2001; Hulicka & Grossman, 1967; Touron et al., 2010; but see Dunlosky & Hertzog, 1998; Hulicka et al., 1967). Instead, what appeared to ultimately limit older adults' source memory were declines in the ability to bind information. Incidental memory for digit-symbol associations, but not mediator-based strategy use, mediated the age-group effect on source memory, supporting the associative-deficit hypothesis (Naveh-Benjamin, 2000). This conclusion concurs with the common finding that production deficiencies only partially contribute to the age-related associative memory deficit (Bailey et al., 2009; Dunlosky & Hertzog, 1998, 2001; but see Naveh-Benjamin et al., 2007).

It is important to acknowledge that we only examined strategy use during encoding. Strategy deficiencies at retrieval might contribute to the age-related source-memory deficit. Dunlosky et al. (2005) found that even with equivalent memory benefits of mediator-based strategies across age groups, older adults were impaired in retrieving and accurately decoding mediators, and this deficit contributed to age-related differences in associative memory. Similarly, Naveh-Benjamin et al. (2007) found particular benefits in older adults if instructions to use mediator-based strategies also emphasized attempting to retrieve the mediator at test. Dew and Giovanello (2010) recently suggested that older adults' associative memory is fully intact on implicit tests, which minimize strategic retrieval demands. Our studies have focused on strategy distributions (i.e., how frequently each strategy is used) and memory-improvement aspects of strategy execution. Age-related differences might exist in other aspects of strategy execution (cf. Lemaire, 2010). For example, mediator generation may particularly tax older adults' cognitive resources (cf. Naveh-Benjamin et al., 2005), and there may be differences between young and older adults' strategy selection for word–source pairs with differing properties (cf. Rowe & Schnore, 1971). Lastly, we were not able to compare the efficacy of individual strategies (e.g., imagery vs. sentence); future research may do so using specific strategy instructions (choice/no-choice methodology; Siegler & Lemaire, 1997).

Although encoding strategy production and utilization do not seem to contribute to age-related differences in source memory, use of mediator-based strategies explained substantial variance in source memory and consistently emerged as a predictor of individual differences in source memory in stepwise regressions among various cognitive abilities. Importantly, even though source encoding often occurs incidentally (e.g., Malmberg & Shiffrin, 2005), our experiments show that it can be strategically improved and that participants readily use associative encoding strategies on standard laboratory source-monitoring tasks. Our experiments examined intentional source encoding, but use of such strategies may also occur in settings in which source encoding is incidental, depending on how much importance participants attach to the manipulated context features or whether context features spontaneously trigger mediator-based processing (e.g., bolded text type may trigger thinking about word importance). We believe that strategic encoding of sources is an important aspect of source monitoring, both in and outside the laboratory. There currently is a pronounced interest in the neural basis of source memory (see Mitchell & Johnson, 2009, for a review), and interpretation of brain activity during source monitoring may benefit from controlling for encoding strategy (Kirchhoff, 2009). Fortunately, our findings suggest that retrospective strategy reports are sufficiently valid, allowing strategy assessment without disrupting the actual source-monitoring task. Lastly, our findings demonstrate that source memory of adults of varying ages can be improved with simple strategy instructions.

Footnotes

1 There were some noteworthy age-related differences within the no-mediator strategies: (a) Young adults spontaneously used rote repetition more frequently, $t(40) = 2.82$, $p = .007$, $d =$

0.89, but no age-related difference in repetition use occurred if imagery was instructed, $t < 1$. (b) Older adults were also generally more likely to use no strategy or a word-only strategy, $F(1, 80) = 7.70$, $p = .007$, $\eta_p^2 = .09$, and this effect was equal across conditions (no interaction), $F(1, 80) = 1.65$. These differences were not included in the regression analyses on individual differences in source memory to avoid multicollinearity. However, separate regression analyses showed that neither the age-related difference in rote repetition nor none/word-only use mediated the age-group effect on source memory.

2 To maximize the number of participants included in the analysis, we used the single-source CSIM when source memory could only be estimated on one of the sources for a participant.

3 Strategy report response times (in ms) were submitted to a 2 (age group) × 2 (report time: concurrent vs. retrospective) mixed ANOVA. Older adults generally gave slower responses, $F(1, 53) = 25.77$, $p < .001$, $\eta_p^2 = .33$. Report response times did not generally differ ($F < 1$), but the age group and time factor interacted, $F(1, 53) = 9.21$, $p = .004$, $\eta_p^2 = .15$. Whereas young adults were faster on the retrospective ($M = 1{,}867$, $SE = 170$) compared with the concurrent report ($M = 2{,}450$, $SE = 294$), $t(29) = 2.08$, $p = .05$, $d = 0.41$, older adults were slower on the retrospective ($M = 5{,}207$, $SE = 606$) compared with the concurrent report ($M = 4{,}210$, $SE = 486$), $t(24) = 2.16$, $p = .041$, $d = 0.45$. It appears that older adults took particularly longer to retrospectively retrieve information about strategy use. Retrospective report response times did not differ between the concurrent + retrospective and the retrospective-only conditions (young: $M = 2{,}329$, $SE = 254$; older: $M = 6{,}099$, $SE = 975$) for either age group (Fs ≤ 1.47).

4 Unlike Experiment 1, there were no age-related differences in average use of the individual strategies.

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