Relate it! Objective and subjective evaluation of mediator-based strategies for improving source memory in younger and older adults[*]

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Abstract:

The present study examined younger and older adults' ability to improve their source memory for different types of sources through imaginal and verbal (sentence) mediators. Younger (18–29 years) and older (60–75 years) adults' strategy use and source memory for either text-type (bold vs italic) or person (woman vs man) sources was assessed; strategy use was either spontaneous or the generation of imaginal mediators was instructed before encoding. Younger and older adults did not differ in spontaneous use of mediator-based strategies; however, older adults generated more images but fewer verbal mediators than younger adults. Participants were able to increase mediator generation when instructed to, resulting in substantial increases in both item and source memory for the instructed conditions in both age groups. Use of verbal mediators was more likely for the more concrete person sources for which source memory was generally better. Importantly, these objective benefits of mediator-based strategies translated into subjective benefits for both younger and older adults: Increased use of either mediator type was correlated with lower experienced task difficulty; the instructions to use imaginal mediators resulted in a significant decrease in difficulty ratings on the group level. Participants were generally able to monitor mediator benefits to both item and source memory and accurately judged mediator strategies (especially imagery) as more effective than repetition; older adults, however, rated all strategies as less effective than younger adults. Implications of these findings, especially for neuropsychological studies on source monitoring, are discussed.

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Article:

1. Introduction

Remembering the source of information (i.e., when, where, how and from whom information was originally learned; Johnson, Hashtroudi, & Lindsay, 1993) is important in many situations. For example, merely knowing that one of your friends is allergic to peanuts is not very helpful. You must remember which friend told you about their allergic reactions to avoid bringing a dish with peanuts to their house. Unfortunately, adults of all ages, but especially older adults, often only know that information was learned previously but cannot remember precise source details (Boywitt, Kuhlmann, & Meiser, 2012; Chalfonte & Johnson, 1996; Kuhlmann & Boywitt, 2016; Old & Naveh-Benjamin, 2008; Yonelinas, 2002). The present study thus examines younger and older adults' ability to strategically improve their source memory.

1.1. Strategically improving associative memory

Successful source memory requires binding or associating item and source (context) information (Chalfonte & Johnson, 1996). Consequently, source memory draws on associative memory processes (Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). On a neural level, this item–source association is thought to be primarily accomplished in medial temporal lobe regions, particularly the hippocampus (see Mitchell & Johnson, 2009, for an overview). But can people strategically improve their encoding of associative information?

Most research on associative encoding strategies has focused on how people encode unrelated noun-pairs (e.g., dog—spoon) such that they can later successfully retrieve one of the nouns when cued with the other (e.g., dog—?). This research has repeatedly found that people remember such associations best when they generate a *mediator* connecting the to-be-associated information (see Richardson, 1998, for a review). According to strategy reports, people spontaneously use both mental images (e.g., visualizing a dog licking a spoon) and verbal sentences (e.g., reasoning that dog goes with spoon because dogs love to lick peanut butter off a spoon) as mediators. Importantly, even people who do not use mediators spontaneously can successfully generate them for most noun-pairs when instructed to, such that instructions to use mediators improve associative memory (e.g., Hulicka & Grossman, 1967; Richardson, 1998). Further, mediator-based strategies also improve memory for the individual items in the association (i.e., the words *dog* and *spoon* in our example) so they broadly benefit memory (Naveh-Benjamin, Brav, & Levy, 2007).

Unfortunately, research on source memory has not paid much attention to encoding strategies, despite evidence that mediator-based strategies improve associative memory. Indirect early evidence that encoding strategies also play a role in source memory stems from studies showing that intentional source encoding instructions improve source memory (Chalfonte & Johnson, 1996). Even for incidental source memory there is evidence that a self-referential focus during encoding (i.e., focusing on one's own emotional reactions to the presented information) impairs memory for external sources (Johnson, Nolde, & De Leonardis, 1996; Mather, Johnson, & De

Leonardis, 1999). Similarly, participants achieve better source memory when asked to think about the item–source relationship than when asked to think about the item only (Bisol Balardin et al., 2009; Glisky, Rubin, & Davidson, 2001). Recently, we more systematically explored what participants exactly do when trying to encode item–source associations and found that they (a) spontaneously generated imaginal or verbal mediators for about 30–40% of the trials for which source memory was better than for trials on which another strategy (e.g., repetition) or no/word-only strategies were used, and (b) that instruction to use imaginal mediators substantially increased mediator-based strategy use and, consequently, source memory (Kuhlmann & Touron, 2012).

In summary, although little is yet known about encoding strategies in source memory, there is clear evidence that source memory can be strategically improved, particularly through the generation of mediators. On a neural level, frontal-lobe areas are crucial for the self-initiation of encoding strategies (Kirchhoff, 2009). Indeed, frontal lesions cause source-memory deficits and although most studies have focused on the contribution of frontal-lobe areas to evaluation and monitoring processes during source retrieval, there is some evidence for its role for source encoding (see Mitchell & Johnson, 2009, for an overview).

Given its theoretical and practical relevance for source memory, further research on mediator-based strategies is desirable. In the present study, we strove to replicate our previous findings regarding the benefits of mediator-based strategies to source memory (Kuhlmann & Touron, 2012) as well as to extend them by gaining novel insight about younger and older adults' mediator use across different source-monitoring tasks. Specifically, we extended our previous research by examining the effects of source type and by differentiating between mediator type (imaginal vs verbal). In noun-pair learning, noun concreteness (or its close correlate imageability) has been shown to particularly increase the use of imaginal mediators (Richardson, 1998; Rowe & Schnore, 1971; Tournier & Postal, 2011) whereas verbal mediators are more likely for abstract material. Further, some studies found that imaginal mediators are more effective (i.e., result in greater memory improvement) for concrete material (e.g., Dirkx & Craik, 1992; Hinault, Lemaire, & Touron, 2016). We therefore deemed it plausible that sources may differ in their affordability of the different types of mediators as well as in their affordability of mediator generation in general. Although distinct general classes of sources have been defined (i.e., internal vs external; Johnson et al., 1993) little is known about differences between types of sources within each class. Within the class of external sources (the focus of the present study), Boywitt and Meiser (2012) found that item–intrinsic sources (e.g., font color) are incidentally better remembered than item–extrinsic sources (e.g., color of an object near the item but not part of the item), presumably due to their automatic capture of attention (see also Mather, 2007). For intentional source learning (focused on here), no differences emerged. However, it seems plausible that it may be easier to intentionally generate a mediator for some external sources (intrinsic or extrinsic) than for others. We considered two common source manipulations (cf. Johnson et al., 1993): words presented in perceptually different text-types (e.g., bold vs italic text types) or presented by two persons (e.g., a man vs a woman). We assumed that it is easier to generate mediators, especially imaginal ones, for more concrete person sources than for rather abstract text types.

Additionally, we strove to evaluate the effectiveness of imaginal versus verbal mediators for source memory in more detail. Richardson (1998) reported that imaginal mediators are particularly effective for noun-pair learning, more so than verbal mediators. In contrast, Dunlosky, Hertzog, and Powell-Moman (2005) found no differences in noun-pair recall after instructions to use imaginal versus verbal mediators. The benefits may depend on the type of material studied: In noun-pair learning, imaginal mediators appear more effective for encoding concrete word pairs whereas verbal mediators appear more effective for encoding abstract word pairs (Hinault et al., 2016). Therefore, we examined whether the effectiveness of imagery instructions for source memory varies by source type (rather abstract text-type sources vs more concrete person sources) and also separately evaluated the relation between imaginal versus verbal mediators and source memory for participants who spontaneously used both mediators.

1.2. Can older adults strategically improve their source memory?

Memory impairments in older age are not surprising. However, it is notable that age-group differences in memory are much more pronounced on certain memory tasks than on others. In general, age-related differences are greater for recall than recognition (see Danckert & Craik, 2013, for a recent review and further evidence). More specifically, age-related differences (on both recall and recognition) are much more pronounced when memory for associations is tested as opposed to when only item memory is tested (see Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995, for meta-analyses). Because older adults remember the individual item information of noun-pairs (i.e., the nouns) or item–source pairs (i.e., which items and which sources were shown) quite well but struggle with remembering their specific association, it has been proposed that aging specifically impairs associative binding processes in memory (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000). This fits with neurological studies showing that aging is associated with shrinkage of medial temporal regions, especially of the hippocampus (Raz, Rodrigue, Head, Kennedy, & Acker, 2004). Indeed, older adults' source-memory deficit is accompanied by decreases in hippocampal activity (Dennis et al., 2008; Mitchell, Johnson, Raye, Mather, & Esposito, 2000; see Mitchell & Johnson, 2009, for a review).

Given this, it is desirable to find means to effectively improve source memory in older adults. Generally, there is much evidence that encoding strategies improve memory in old age (see Gross et al., 2012; Verhaeghen, Marcoen, & Goossens, 1992, for meta-analyses), even for older adults suffering from neurodegenerative diseases such as Alzheimer's dementia (Sitzer, Twamley, & Jeste, 2006). Impressively, several studies found that older adults were able to improve their memory through effective encoding strategies to the same extent as younger adults (e.g., Hertzog, McGuire, & Lineweaver, 1998) and this also holds for associative (noun-pair) memory (e.g., Dunlosky & Hertzog, 2001; Hulicka & Grossman, 1967; Naveh-Benjamin et al., 2007). It must be noted, however, that other studies found reduced (yet substantial) memory benefits from encoding strategies in older adults, especially for complex multi-step mnemonic techniques (Kliegl, Smith, & Baltes, 1989, 1990; Verhaeghen & Marcoen, 1996).

Fortunately, there is initial evidence that strategies improve older adults' source memory: Generally, healthy older adults benefit substantially from focusing on the item–source relationship during encoding (compared to focusing on the item only; Bisol Balardin et al., 2009; Glisky et al., 2001). More specifically, we found no evidence for age-related deficits in producing or benefitting from mediator-based strategies on source-memory tasks (Kuhlmann & Touron, 2012). Although older, like younger adults, spontaneously generated mediators for only 30–40% of the item–source pairs, they were just as able as younger adults to increase their mediator generation when instructed to and, importantly, showed substantially improved source memory after instructions to use mediators (about 10% increase in both age groups). However, apart from the need to replicate the exciting finding that mediator-based encoding strategies improve source memory in older adults, much remains to be explored. The questions raised regarding mediator modality and source type are particularly relevant to examine in older adults. In terms of mediator type, research points to pronounced age-related deficits in mental imagery, which may stem from the typical declines in basic cognitive abilities such as processing speed, working memory, and inhibitory functioning (Bruyer & Scailquin, 2000). Indeed, use of imagery strategies and memory benefits from imagery were found to correlate with basic cognitive abilities in older adults (Baltes & Kliegl, 1992; Verhaeghen & Marcoen, 1994). One study even reports that older adults were reluctant to use imaginal mediators for learning noun-pairs (Hulicka, Sterns, & Grossman, 1967). In contrast, descriptions of imaginal (and verbal) mediators for noun-pairs were not found to qualitatively differ between older and younger adults (Dunlosky et al., 2005) and in our previous study, instructions to generate imaginal mediators for item–source pairs improved older adults' source memory just as much as younger adults'. However, our previous analyses did not distinguish between imaginal and verbal mediators and it is thus necessary to more closely compare older adults' use of imaginal versus verbal mediators. With regards to source type, older adults increase the use of imaginal mediators for concrete noun-pairs but use verbal mediators for abstract noun-pairs, similar to the effects in younger adults (Rowe & Schnore, 1971; Tournier & Postal, 2011). Interestingly, in the study by Rowe and Schnore, age-group differences in the use of imaginal mediators were only present for abstract pairs but not for concrete material. Further, meta-analyses on the age-related source-memory deficit reveal that it varies by source type (Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995). Therefore, it is interesting to examine to what extent older adults' mediator use is affected by source type and whether older adults are better able to use imaginal (or verbal) mediators for certain types of sources (e.g., more concrete person sources) than others (e.g., more abstract text-type sources).

1.3 Subjective benefits and evaluation of item–source encoding strategies

In addition to objectively evaluating the benefits of mediator-based strategies for source memory, the present study also examined the subjective experience of mediator use. For one, we asked whether mediators use at encoding decreases experienced task difficulty. Further, we asked to what extent people can monitor source-memory benefits from mediator use. Because subjective memory complaints are frequent in older adults and not always related to their actual performance (e.g., Hertzog, Park, Morrell, & Martin, 2000), it is of particular interest to evaluate whether an effective strategy intervention also results in older adults subjectively perceiving improved performance (Floyd & Scogin, 1997).

Furthermore, we assessed subjective beliefs about the effectiveness of mediator-based (and other) strategies for source memory. Accurate knowledge about strategy effectiveness is key for the adequate metacognitive control of learning (Hertzog & Dunlosky, 2004). Hertzog, Price, and Dunlosky (2012) found that both younger and older adults did not initially appreciate the benefits of mediator-based strategies over rote repetition for encoding noun-pairs, but learned the effectiveness of mediator-based strategies from task experience (see also Dunlosky & Hertzog, 2000). However, older adults did so to a lesser extent than younger adults, which may influence their future encoding strategy use. Older adults also typically underestimate their ability to strategically control memory performance (Lachman, 1991). It is important to document whether older adults also under-appreciate the effectiveness of mediator-based strategies for source memory, which may render them less likely to apply such strategies in some situations (e.g., when strategy application is effortful; cf. Bottiroli, Dunlosky, Guerini, Cavallini, & Hertzog, 2010) and may dampen their benefits from strategy training (unless control beliefs are also addressed by the training; Lachman, 2006; West, Bagwell, & Dark-Freudeman, 2008). More generally, given that typical source-memory studies do not instruct or otherwise control encoding strategy use, it is important to assess the degree of interindividual differences in strategy evaluation which may contribute to interindividual and group differences in source-memory performance.

1.4. Overview of the present study

The goal of the present study was to examine the impact of mediator-based encoding strategies on source memory in younger and older adults. Although one goal of our research was to replicate the core findings of Kuhlmann and Touron (2012), namely that mediator generation and benefits to source memory are comparable between younger and older adults, we further strove to extend these findings in several important ways. First, we separately examined use of imaginal versus verbal mediators and tested for age-group differences in mediator-type preference. Second, we examined whether sources differ in mediator affordability. To this end, we employed two common external source manipulations (cf., Johnson et al., 1993). We presented words in either two different text types (bold vs italic text) or along with two different persons (a woman vs a man, represented by a name and a picture). We predicted that the more concrete person sources would facilitate mediator generation in general, especially for imaginal mediators, and we similarly expected greater memory benefits of (imaginal) mediators to source memory for the person sources. A better understanding of how and to what extent preferences for imaginal versus verbal encoding strategies vary between conditions (i.e., age groups, source types) has important implications for neuropsychological research on source memory because these strategies are related with different patterns of brain activity (Kirchhoff, 2009; Leshikar, Duarte, & Hertzog, 2012), a point we will further elaborate in the Discussion. Third, the present study's design allowed us to examine whether the benefit of imagery instructions varies with source type and we also compared source memory by mediator type. Fourth, the present study examined whether the objective source-memory benefits of mediators also translate into subjective benefits, particularly the experience of more ease for the source-memory task. Fifth, we explored our participants' metacognitive monitoring of strategy effectiveness. We expected good relative monitoring of the effectiveness of mediator (imaginal, verbal) strategies versus non-mediator strategies (repetition) but suspected that older adults might generally underestimate strategy effectiveness (cf., Hertzog et al., 2012; Lachman, 1991). Finally, in order to more broadly evaluate the mediator-strategy benefit to performance on source-monitoring tasks we analyzed effects on item memory in addition to those unique for source memory (i.e., memory for the item–source association).

2. Method

2.1. Participants

Eighty undergraduates participated for course credit. Data from one were excluded due to source-memory performance more than 3.5 standard deviations below the condition's (person sources + imagery instructed) mean, resulting in a final sample of 79 younger adults (18–29 years, *M* = 19.1, *SE* = .21).[1] Eighty community-dwelling senior citizens (60–75 years, *M* = 67.1, *SE* = .48) participated for monetary compensation ($10/h). All participants were native speakers of English. Persons who had a stroke, heart attack, major head trauma, neurological disorder (e.g., major epilepsy, Alzheimer's disease, Parkinson's, etc.), uncontrolled high blood pressure (≥140 mmHg systolic), depression (current or within the past 6 months) or who were taking medication affecting cognition were excluded from participation. Older adults were prescreened for these criteria on the phone and all participants completed a detailed health and demographic questionnaire after the experiment. Sample characteristics, showing age-group differences typical in cognitive aging research, are in Table 1.[2]

Table 1 – Sample characteristics.

Measure	Age group	Text type source		Person sources	
		Spontaneous	Instructed	Spontaneous	Instructed
Age	YA	18.60 (.17)	19.10 (.26)	19.65 (.71)	18.83 (.28)
	OA	66.65 (.95)	66.20 (.95)	67.50 (.87)	67.85 (1.06)
Processing speed (DS completion)[b]	YA	63.60 (2.98)	62.05 (2.28)	62.00 (2.32)	59.21 (1.67)
	OA	54.50 (2.61)	47.50 (2.94)	44.05 (2.93)	43.90 (2.23)
Incidental associative memory (DS memory)[a]	YA	7.85 (.41)	7.70 (.29)	6.90 (.48)	7.42 (.45)
	OA	5.10 (.61)	5.55 (.55)	4.30 (.49)	5.40 (.54)
Vocabulary[a]	YA	28.60 (.58)	27.70 (.61)	28.55 (.84)	28.21 (.75)
	OA	34.30 (.61)	33.50 (.67)	31.90 (1.25)	33.60 (.71)
Years of education[b]	YA	12.35 (.17)	12.85 (.24)	12.65 (.25)	12.33 (.14)
	OA	16.55 (.55)	15.80 (.57)	14.40 (.61)	14.95 (.51)
Subjective health rating[a]	YA	4.25 (.14)	4.45 (.14)	4.35 (.17)	4.11 (.14)
	OA	4.75 (.10)	4.55 (.14)	4.40 (.20)	4.75 (.10)
Number of medications[a]	YA	0.75 (.20)	0.90 (.32)	0.85 (.26)	0.67 (.24)
	OA	2.45 (.34)	2.80 (.45)	3.30 (.50)	2.20 (.40)

Note. Means are displayed with their standard error in parentheses. There were 79 younger [but due to experimenter error demographic information (exact age, years of education, health rating and medication number) is missing for one younger adult] and 80 older adults. Processing speed = total number of correctly copied symbols within 90 sec on the digit-symbol substitution test (Wechsler, 1981). Vocabulary = proportion correct (out of 20) on the Shipley Vocabulary Test (Zachary, 1986). Health rating = subjective rating compared to state of perfect health (1 = *very poor* to 5 = *very good*).

[a] Age-group difference significant, $p < .05$.

[b] Age-group difference significant but also significant difference within the older-adult conditions (see Footnote 2).

2.2. Design and material

The design was a 2 (age group: younger *vs* older) × 2 (source type: text types *vs*persons) × 2 (strategy instructions: spontaneous *vs* imagery instructed) factorial with all factors manipulated between subjects. For the text-type sources, words were presented in bold versus italics; for the person sources, the words were presented by “Tom” versus “Mary” (pictures of a middle-aged man “Tom” *vs* a middle-aged woman “Mary”, taken from Minear & Park, 2004). Participants either received no encoding-strategy instructions (i.e., spontaneous strategy use) or instructions to generate interactive images for the word–source pairs. We chose to instruct imagery rather than use of verbal (sentence) mediators in order to more closely follow up on our previous study (Kuhlmann & Touron, 2012) and because some research suggests that imaginal mediators are particularly effective for improving associative memory (Richardson, 1998; but see; Dunlosky et al., 2005). Notably, this may depend on the concreteness of the study material (Hinault et al., 2016), that is the source type in the present study. As discussed later, the lack of verbal-mediator instruction conditions limits our ability to draw definite conclusions about the effectiveness of verbal mediators compared to imaginal mediators. Complete crossing of source concreteness and strategy instructions resulted in four experimental conditions to which participants of each age group were randomly assigned (n = 20 per condition). Although statistical power to detect between-group differences was only sufficient to detect large effects [i.e., for d = .80 power = .69 (two-tailed)/.80 (one-tailed); computed with GPower*3 by Faul, Erdfelder, Lang, & Buchner, 2007], differences in mediator-instruction effects between younger and older groups have been detected with comparably small group sizes (Naveh-Benjamin et al., 2007). Tests were higher powered for detecting a general production or utilization deficiency across source types (i.e., n = 40 per age-group and instruction condition).

One hundred one- or two-syllable nouns with high imagery and concreteness (≥6 on 7-point scale) were randomly selected from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982), avoiding synonyms or phonological similarities. Mean ratings for the selected noun pool were 6.33 (SE = .02) on imagery, 6.57 (SE = .02) on concreteness, and 59.4 (SE = 7.43) on Kucera–Francis frequency. For each participant, a random 50 nouns served as study targets and the remaining 50 as recognition-test distracters.

2.3. Procedure

Participants were tested in age-homogeneous groups (up to 6). After consenting, participants completed a demographic questionnaire and passed a (corrected) near visual-acuity assessment. Verbal knowledge was measured with the self-paced paper-based Shipley Vocabulary Test (Zachary, 1986) requiring choosing synonyms for 40 target words out of five options. Processing speed was measured with the digit-symbol substitution test (Wechsler, 1981) requiring participants to copy symbols paired with digits (1–9) for a random digit sequence for 90 sec (see DS completion in Table 1). Immediately afterwards, we assessed memory for the digit-symbol associations cueing participants with the digits and asking them to draw in the symbol (self-paced; see DS memory in Table 1). We interpret this as a measure of incidental associative memory because participants were not instructed to memorize associations during DS completion (cf. Kuhlmann & Touron, 2012).

Participants independently completed the computerized source-monitoring task. Instructions emphasized that both word and source memory would be assessed. For the imagery-instructed conditions, information about the benefit of interactive imagery on associative memory was given. For the text type sources, provided examples were picturing images of bold words wide and big (e.g., a forest with wide trees) and images of italic words slanted and skinny (e.g., a forest with skinny, slanted trees). For the person sources, provided examples were picturing either the man or the woman interacting with the word “jacket” (e.g., Tom playing tennis in a training jacket or Mary in the snow in a warm winter jacket). Participants then practiced generating images for each source (not scored) and were encouraged to come up with an image for each presented word–source pair.

During study, 50 words (randomly selected from the pool) appeared centered, one at a time. A random half appeared in one source (text type or person) and the remaining half in the other. For the person sources, the words appeared under the picture and the name. Order of word–source pairs was random with the restriction of no more than three consecutive presentations in the same source. Word–source pairs remained on the screen for 10s, separated by a 500 msec blank screen with a centered fixation cross. Upon studying all 50 pairs, participants verified simple math problems for 1.5 min and then read instructions for the memory test. In the test, each word from the pool (studied or unstudied, random order) appeared centered on the screen without source information (i.e., regular text type and no pictures/names). Participants responded by clicking response fields with the mouse. Assignment of the response options to the right versus left field was counterbalanced across participants. Participants first decided whether a word was "old" (studied) or "new." After responding "old," they next indicated the text type (abstract-sources conditions) or person (concrete-sources conditions). After making this source attribution or immediately after a "new" response, the next test word appeared. Test responses were self-paced.

Next, instructions for the retrospective item-level strategy questionnaire appeared. For participants in the spontaneous conditions this was the first mentioning of encoding strategies. Imaginal mediators, sentence mediators, and rote repetition were described with examples. The interest in associative encoding strategies involving both the word and its source was emphasized and that "Other" should only be chosen if a different strategy accomplishing this was used. Any strategies just involving the to-be-studied words as well as use of no encoding strategy were reported as "None/Word Only." Instructions ensured that choosing the same strategy for each word–source pair, including "None/Word Only," was fine as was choosing many different strategies. The 50 studied word–source pairs were then presented again, in a new random order. Presentations of each word and its source were identical to the original study screens with the addition of response fields labeled "Imagery," "Sentence," "Repetition," "Other," and "None/Word Only" (in that order). Response selection was self-paced. Retrospective strategy reports have the distinct advantage of eliminating the need to mention encoding strategies in the instructions before completion of the memory task, which may have reactive effects on subsequent strategy use (Dunlosky & Hertzog, 2001). We have previously shown that these retrospective strategy reports for item–source learning are reasonably consistent with concurrent ones for both younger and older adults (Kuhlmann & Touron, 2012).

Finally, participants completed a paper-based questionnaire assessing subjective task experience and metacognitive beliefs about the strategies and their memory performance. Specifically, participants were asked to rate the overall difficulty of the task on a 7-point scale (1 = *not at all difficult* to 7 = *very difficult*). In the imagery-instructed conditions, participants were further asked to rate the difficulty of generating images for the word–source pairs on the same scale. All participants were asked to separately rate the effectiveness of sentence mediators, imaginal mediators, and repetition (in that order) on 7-point scales (1 = *not at all effective* to 7 = *very effective*). Finally, participants were asked to estimate the number of old words (out of 50) that they correctly recognized as old on the test and the number of recognized words (out of their estimate) which they further attributed to the correct source. Participants were then debriefed and compensated for their time.

3. Results

3.1. Strategy use

Table 2 presents the mean proportion of trials on which participants reported using each encoding strategy. First, we analyzed the frequency of using no/word-only strategies, that is how often participants failed to use a task-appropriate item–source encoding strategy, in a 2 (age group) × 2 (source type) × 2 (imagery instructions) analysis of variance (ANOVA). There was no significant age-group difference, $F < 1$, and age group also did not interact with any other factor, all $F < 1$. As expected, participants of both age groups were less likely to use no/word-only strategies for person sources than for text-type sources, $F(1, 151) = 8.99$, $p = .003$, $\eta_p^2 = .06$, and after instructions to use imaginal mediators than spontaneously, $F(1, 151) = 20.52$, $p < .001$, $\eta_p^2 = .12$. No other effects were significant.

Table 2 – Means and standard errors of proportions of strategy use.

		Mediator strategies			Repetition	Other	None/word-only
		Imaginal	Verbal	Total			
Spontaneous	Text types	YA: .37 (.06)	YA: .07 (.03)	YA: .45 (.07)	YA: .17 (.05)	YA: .08 (.02)	YA: .31 (.07)
		OA: .41 (.07)	OA: .05 (.03)	OA: .46 (.08)	OA: .10 (.05)	OA: .09 (.04)	OA: .36 (.08)
	Persons	YA: .33 (.06)	YA: .25 (.06)	YA: .58 (.08)	YA: .16 (.07)	YA: .11 (.05)	YA: .15 (.04)
		OA: .50 (.07)	OA: .12 (.04)	OA: .62 (.07)	OA: .06 (.05)	OA: .14 (.05)	OA: .19 (.04)
Imagery instructed	Text types	YA: .66 (.07)	YA: .13 (.05)	YA: .80 (.07)	YA: .04 (.02)	YA: .04 (.02)	YA: .12 (.05)
		OA: .69 (.07)	OA: .07 (.05)	OA: .76 (.06)	OA: .07 (.05)	OA: .07 (.03)	OA: .10 (.04)
	Persons	YA: .45 (.07)	YA: .37 (.07)	YA: .82 (.06)	YA: .07 (.03)	YA: .08 (.05)	YA: .03 (.01)
		OA: .60 (.05)	OA: .17 (.05)	OA: .77 (.05)	OA: .06 (.03)	OA: .07 (.03)	OA: .10 (.03)

Note. Displayed is the mean proportion of trials on which a strategy was retrospectively reported to have been used in the specific condition (standard error in parentheses). For mediator-based strategies, "Total" was computed by summing the proportion of image and sentence use for each participant. YA = younger adults ($n = 19$ in the imagery-instructed persons condition, 20 in all other conditions). OA = older adults ($n = 20$ for each condition).

Next, we examined use of non-mediator item–source encoding strategies. Reports of other strategies were rare (grand mean proportion = .08) and, importantly, did not differ by age group, source type, or strategy instructions, largest $F(1, 151) = 1.93$, $p = .167$ (for a numerical decrease in other strategies after imagery instructions). Thus, our options captured most of the strategies used by participants (see Kuhlmann & Touron, 2012, Experiment 2b, for a closer examination of other strategies people might use on source-monitoring tasks). Use of repetition (of both the item and its source) was also infrequent (grand mean proportion = .09) and neither differed by age group, $F(1, 151) = 1.55$, $p = .216$, nor by source type, $F < 1$. The effect of imagery instructions was marginal, $F(1, 151) = 3.46$, $p = .065$, $\eta_p^2 = .02$, with a tendency for repetition use to decrease after imagery instructions. None of the interactions were significant, all $F \leq 1.96$, $p \geq .163$.

Finally, we analyzed use of mediator-based strategies, including mediator type (image *vs*sentence) as a within-subjects factor alongside the between-subjects factors (age group, source type, strategy instructions) in a mixed ANOVA. Replicating Kuhlmann and Touron (2012), there was no age-group difference in average use of mediator-based strategies, $F < 1$. Interestingly, however, age group interacted with mediator type, $F(1, 151) = 8.80$, $p = .004$, $\eta_p^2 = .06$. Follow-up simple main effects analyses revealed that older adults were more likely to use imaginal mediators than younger adults, $F(1, 151) = 4.25$, $p = .041$, $\eta_p^2 = .03$, whereas younger adults were more likely than older adults to use verbal mediators, $F(1, 151) = 9.28$, $p = .003$, $\eta_p^2 = .06$. Therefore, there was no age-group difference in average use of mediator-based strategy (compare also the “Total” column in Table 2) but the age groups appear to prefer different types of mediators (older → imaginal, younger → verbal). Importantly, however, a strong main effect of strategy, $F(1, 151) = 103.69$, $p < .001$, $\eta_p^2 = .41$, indicated more use of imaginal than verbal mediators in both age groups. The main effect of source type was marginal, $F(1, 151) = 3.02$, $p = .084$, $\eta_p^2 = .02$, and, importantly, interacted with strategy, $F(1, 151) = 9.19$, $p = .003$, $\eta_p^2 = .06$. Whereas use of imaginal mediators was numerically but not significantly less for person sources compared to text sources, $F(1, 151) = 1.82$, $p = .179$, participants were more likely to use verbal mediators for the person sources, $F(1, 151) = 17.11$, $p < .001$, $\eta_p^2 = .10$. This preference for verbal mediators for the person sources was more pronounced in the younger adults, but the age group × source type × strategy interaction was only marginal, $F(1, 151) = 3.58$, $p = .060$, $\eta_p^2 = .02$. Finally, there was a strong main effect of imagery instructions, $F(1, 151) = 31.74$, $p < .001$, $\eta_p^2 = .17$, which interacted with strategy, $F(1, 151) = 4.15$, $p = .043$, $\eta_p^2 = .03$. First and foremost, imagery instructions increased use of imagery, as intended, $F(1, 151) = 18.23$, $p < .001$, $\eta_p^2 = .11$. Further, imagery instructions marginally increased use of verbal mediators, $F(1, 151) = 3.08$, $p = .081$, $\eta_p^2 = .02$, probably due to some participants preferring verbal to imaginal mediators. No other effects were significant, all $F \leq 2.63$, $p \geq .107$. Age group did not interact with the effects of the imagery instructions, indicating that older adults were as able as younger adults to increase the use of imaginal mediators when instructed. Indeed, older adults overall generated more imaginal mediators, whereas some younger adults seemed to prefer verbal mediators, particularly for person sources.

Table 3 presents correlations between the use proportions for each strategy and various participant characteristics. In order to increase statistical power without artificially inflating correlations through between-condition differences, all variables were first z-standardized within each source type × strategy instruction condition and then correlations were computed across conditions for younger and older adults separately. As evident in Table 3, use of strategies in source-memory tasks was generally not related to processing speed in either age group (replicating Kuhlmann & Touron, 2012), with the one exception that processing speed correlated with older adults' use of verbal mediators. As is evident from the large mean shifts in mediator use between the spontaneous and instructed conditions participants were in general able to use mediators, independent of their basic cognitive abilities.

3.2. Objective evaluation of strategy effectiveness for memory improvement

Mediator-based strategies should improve memory for both the individual items and their association (Naveh-Benjamin et al., 2007). As successful source memory requires both memory for the item and, additionally, for the item–source association (Murnane & Bayen, 1996), any benefits of imagery instructions may thus be due to mediator-based strategies improving item memory, memory for the item–source association, or both. In order to disentangle these effects, we separately analyzed P_r (i.e., hits – false alarms) for item memory and the conditional source-identification measure (CSIM) for source memory. Calculated for each source (e.g., italic text type or “Mary”) separately, single-source CSIM is the proportion of correct source attributions out of all recognized items from that source. Single-source CSIMs for the two text types or the two persons were then averaged (ACSIM). Importantly, (A)CSIM has been formally shown to be generally independent of the level of item recognition (Murnane & Bayen, 1996).[3] Thus, (A)CSIM captures the unique benefits of imagery-instructions/mediator-based strategy use to memory for the item–source association (i.e., source memory), over and above its benefits to item memory.

Table 3 – Correlations between strategy use proportions and participant characteristics, memory performance, and metacognitive measures.

Measure	Imaginal mediator	Verbal mediator	Repetition	Other	No/word-only
Younger adults					
Vocabulary	.20	−.02	−.32**	.07	.01
Education	.32**	−.11	−.08	.14	−.25*
DS completion	−.00	−.09	−.17	−.14	.11
DS memory	−.07	.16	−.13	.05	.03
Item memory (P_r)	.15	.28*	−.34**	.08	−.23*
Source memory (ACSIM)	.24*	.19	−.28*	.00	−.25*
Postdicted item memory	.06	.18	−.29*	.06	−.16
Postdicted source memory	.27*	.20	−.24*	−.29*	−.11
Task difficulty	−.11	−.16	.10	.20	.09
Imaginal mediator effectiveness	.56***	−.11	−.11	.10	−.11
Verbal mediator effectiveness	−.19	.74***	−.13	.05	−.06
Repetition effectiveness	−.11	−.10	.50***	−.08	.02
Older adults					
Vocabulary	−.04	.12	.08	−.13	−.10
Education	−.07	.01	.06	.00	−.03
DS completion	−.11	.25*	.12	−.04	−.16
DS memory	.05	.20	.04	.07	−.26*
Item memory (P_r)	.39***	.26*	−.11	−.11	−.55***
Source memory (ACSIM)	.33**	.29**	−.18*	−.14	−.35***
Postdicted item memory	.23*	.23*	−.08	.08	−.48***
Postdicted source memory	.21	.27*	−.09	−.18	−.22
Task difficulty	−.21	−.24*	.14	.15	.34*
Imaginal mediator effectiveness	.25*	.06	−.21	−.13	−.08
Verbal mediator effectiveness	−.03	.47***	−.09	−.27*	−.10
Repetition effectiveness	−.19	−.04	.29*	−.20	.03

Note. All measures were z-standardized within each source type × instruction condition before computing the correlations aggregated across conditions to increase statistical power without conflating correlations due to mean-level differences between conditions. Correlations are based on 79 younger adults and on 80 older adults (with the exception of postdicted source memory and strategy effectiveness ratings, which were missing for one older adult). Correlations are Pearsons's *r* with the exceptions of task difficulty and strategy effectiveness ratings for which Spearman's rho was computed because these judgments were made on 7-point Likert scales (1 = *not at all difficult* to 7 = *very difficult*).
*$p < .05$; **$p < .01$; ***$p < .001$.

Fig. 1 displays mean P_r and ACSIM scores by condition; each were submitted to a 2 (age group) × 2 (source type) × 2 (strategy instructions) ANOVA. Expectedly, older participants' item and source memory was poorer than younger participants', $F(1, 151) = 5.37$, $p = .022$, $\eta_p^2 = .03$, and $F(1,151) = 4.48$, $p = .036$, $\eta_p^2 = .03$, respectively. Further, as expected there was a significant main effect of strategy instructions on both measures: Both item and source memory were overall significantly better in the imagery-instructed compared to the spontaneous conditions, $F(1,151) = 33.50$, $p < .001$, $\eta_p^2 = .18$, and $F(1,151) = 25.73$, $p < .001$, $\eta_p^2 = .15$, respectively. For item memory, no other main effects or interactions were significant, all $F \leq .1.19$, $p \geq .277$. That is, there were no effects of source type on item memory. In contrast, source concreteness affected source memory, $F(1,151) = 8.16$, $p = .005$, $\eta_p^2 = .05$. As expected, source memory was overall better for the (more concrete) person than the (more abstract) text-type sources. There was no evidence for an interaction between strategy instructions and source type, $F < 1$, suggesting that participants equally benefitted from imagery instructions independent of the source type. Further, despite their general source-memory deficit, older adults improved their source memory with imagery instructions and more concrete person sources as much as younger adults as evidenced by no interactions of these effects with age group, all $F < 1$.

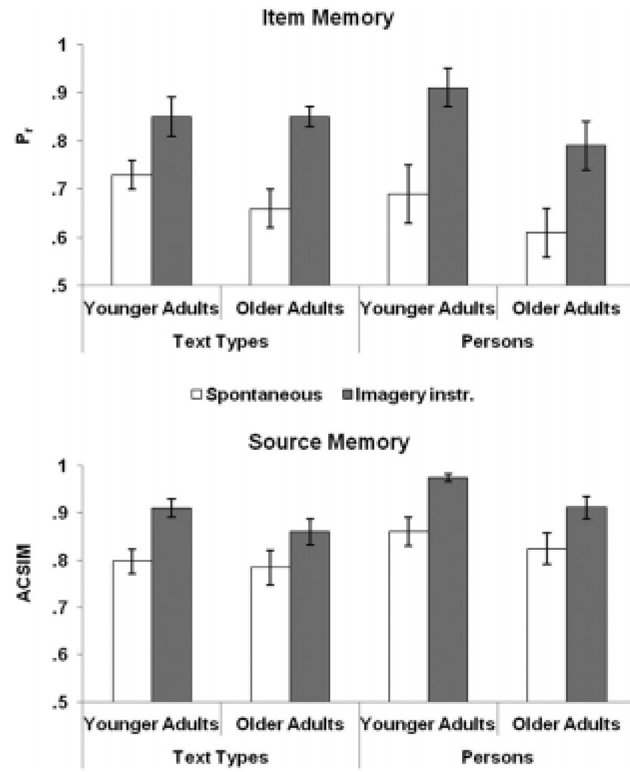

Fig. 1 – Item (P_r, i.e., hits − false alarms; upper panel) and source memory (average conditional source-identification measure – ACSIM; lower panel) by age group, source type, and strategy instructions. Error bars represent the standard error of the mean.

Thus, a simple instruction to generate imaginal mediators was effective for improving both item and source memory in both age groups. Notably, examining the strategy instruction effect underestimates the benefit of mediator-based strategies on memory because, as evident from Table 2, participants were not able to generate mediators for 100% of the source–item pairs in the instructed conditions and participants in the non-instructed conditions spontaneously generated mediators for some pairs. Table 3 thus presents correlations between the proportions of mediator use and item as well as source memory. Again, all variables were *z*-standardized within each source type × instruction condition such that correlations could be computed across conditions to increase statistical power. Generally, such correlational analyses may confound strategy effects with participant effects (Siegler & Lemaire, 1997) but as we showed before strategy use was at large unrelated with participant characteristics (see other correlations in Table 3).[4] In younger adults, only verbal-mediator use was significantly correlated with item memory; in older adults, use of both imaginal and verbal mediators positively correlated with item memory and to a comparable extent (dependent-correlation comparisons via Lee & Preacher, 2013), $z = -.50$, $p = .616$. Both imaginal and verbal mediator use was correlated with source memory in both age groups (only marginal for verbal mediators in younger adults, $r(77) = .19$, $p = .096$). Importantly, correlations between mediator use and source memory did not significantly differ by mediator type within either age group, both $z < 1$, suggesting comparable effectiveness of imaginal and verbal mediators for source memory. Further, correlations between (item and source) memory and (imaginal and verbal) mediator use did not differ between age groups, all $z \leq 1.61$, $p > .10$. Use of repetition and other strategies was not systematically related to item or source memory (with one exception: repetition was significantly negatively correlated with source memory in both age groups). Use of no/word-only strategies was negatively correlated with item and source memory in both age groups.

Finally, we examined how well strategy use predicted interindividual differences in source memory above and beyond basic cognitive abilities. In a stepwise regression, use of imaginal mediators, verbal mediators, as well as rote repetition were considered as possible predictors of source memory alongside age group, DS completion, DS memory, vocabulary, and education (again, all variables were *z*-standardized within each source type × instruction condition). The final model explained 30.7% of the variance in source memory, $F(3,157) = 22.72$, $p < .001$, with three predictors (entered as listed): (1) Incidental associative memory (i.e., DS memory; $\beta = .32$, $p < .001$), (2) imaginal-mediator use ($\beta = .39$, $p < .001$), and (3) verbal-mediator use ($\beta = .34$, $p < .001$). Entered on its own, age group (0 = younger adults, 1 = older adults) significantly predicted source memory ($\beta = -.20$, $p = .013$). Entering the mediator-use variables did not substantially reduce age-group's slope ($\beta = -.18$, $p = .004$) whereas entering DS memory reduced its slope to be nonsignificant ($\beta = -.01$, $p = .881$). Thus, replicating Kuhlmann and Touron (2012), age-related declines in incidental associative memory fully mediated the age-related decline in source memory, Sobel's $z = 2.25$, $p = .025$.

3.3. Subjective evaluation and monitoring of strategy effectiveness

In this final section, we analyze participants' reports about their subjective experience of the source-monitoring task as well as their beliefs about strategy effectiveness and their own source-memory performance. Descriptive statistics for all measures are presented in Table 4.

Table 4 – Means and standard errors for task experience and metacognitive measures.

Strategy instructions	Source type	Task difficulty	Strategy effectiveness rating			Memory postdictions	
			Imaginal mediator	Verbal mediator	Repetition	Item memory	Source memory
Spontaneous	Text types	YA: 4.20 (.29)	YA: 5.60 (.34)	YA: 2.75 (.39)	YA: 3.85 (.38)	YA: .58 (.04)	YA: .72 (.04)
		OA: 4.60 (.38)	OA: 5.00 (.48)	OA: 3.15 (.38)	OA: 3.30 (.33)	OA: .58 (.07)	OA: .69 (.07)
	Persons	YA: 4.15 (.41)	YA: 5.60 (.26)	YA: 4.80 (.35)	YA: 4.00 (.43)	YA: .61 (.05)	YA: .72 (.05)
		OA: 4.00 (.33)	OA: 5.95 (.29)	OA: 4.30 (.41)	OA: 3.70 (.43)	OA: .54 (.05)	OA: .68 (.05)
Imagery instructed	Text types	YA: 3.55 (.44)	YA: 6.25 (.23)	YA: 3.70 (.44)	YA: 3.60 (.36)	YA: .76 (.04)	YA: .81 (.05)
		OA: 3.90 (.38)	OA: 6.20 (.19)	OA: 3.10 (.40)	OA: 3.20 (.43)	OA: .78 (.04)	OA: .80 (.05)
	Persons	YA: 2.84 (.26)	YA: 6.32 (.19)	YA: 5.58 (.34)	YA: 3.89 (.35)	YA: .77 (.04)	YA: .90 (.03)
		OA: 3.35 (.28)	OA: 6.20 (.16)	OA: 4.11 (.50)	OA: 3.21 (.47)	OA: .63 (.04)	OA: .88 (.02)

Note. All measures were assessed after completion of the source-memory test and the retrospective item-level strategy reports. Task difficulty and strategy effectiveness were rated on 7-point scales (1 = *not at all difficult/effective* to 7 = *very difficult/effective*). Source-memory postdiction was computed based on participants postdiction of the number of words they assigned to the correct source divided by the estimated number of words recognized (values larger than 1 were corrected to 1). YA = younger adults ($n = 19$ in the imagery-instructed persons condition, 20 in all other conditions). OA = older adults ($n = 20$ for each condition but strategy effectiveness estimates and postdictions were missing for one older adult in the imagery-instructed persons condition).

3.3.1. Task and imagery difficulty

Participants' ratings of the difficulty of the source-memory tasks (see Table 4 for descriptives) were analyzed in a 2 (age group) × 2 (source type) × 2 (strategy instruction) ANOVA. Despite their performance difference, younger and older adults rated the task equally difficult (grand mean = 3.84, so the task was rated as moderately difficult overall), $F(1, 151) = 1.24$. $p = .267$.

Participants in the person sources conditions rated the task as slightly easier than those in the text-type sources conditions, $F(1, 151) = 3.69$, $p = .057$, $\eta_p^2 = .02$. Most importantly, participants in the imagery-instructed conditions, who used more mediator-based strategies (see 3.1), found the task significantly easier than those without strategy instructions, $F(1, 151) = 11.08$, $p = .001$, $\eta_p^2 = .07$. None of the interactions were significant, all $F < 1$, so this easing effect of imagery instructions held equally for both older and younger adults. When examining correlations between task-difficulty ratings and strategy use individually (see Table 3), more use of image and sentence mediators was correlated with lower ratings of task difficulty in the older adults whereas only the correlation with sentence use was significant in the younger adults. Use of the remaining strategies was generally not related to task-difficulty ratings with the exception that use of no/word-only strategies correlated with higher task-difficulty ratings in older adults.

In the imagery-instructed conditions, participants further rated the difficulty of generating images. Imagery difficulty ratings were quite stable. Participants of both age groups found image generation to be relatively easy for text type sources (younger adults: $M = 2.40$, $SE = .30$; older adults: $M = 2.30$, $SE = .27$) as well as for person sources (younger adults: $M = 2.53$, $SE = .28$; older adults: $M = 2.60$, $SE = .29$). A 2 (age group) × 2 (source type) ANOVA yielded no significant effects, all $F < 1$.

3.3.2. Strategy effectiveness ratings

Participants' strategy effectiveness ratings[5] (see Table 4 for descriptives) were submitted to a 2 (age group) × 3 (strategy: imagery *vs* sentence *vs* repetition) × 2 (source type) × 2 (strategy instructions) repeated-measures ANOVA with Greenhouse–Geisser correction. Overall, older adults rated the strategies as less effective than younger adults did, $F(1, 150) = 5.34$, $p = .022$, $\eta_p^2 = .03$. Effectiveness ratings substantially differed between strategies, $F(1.93, 289.08) = 101.42$, $p < .001$, $\eta_p^2 = .40$. This effect of strategy did not interact with age group, $F < 1$. Overall, imaginal mediators were rated as more effective than sentence mediators and rote repetition, both $p < .001$. Sentence mediators were assigned slightly higher effectiveness than rote repetition, $p = .074$. This effect was qualified by source type, which exhibited a significant main effect (overall higher strategy effectiveness ratings for person sources), $F(1, 150) = 16.05$, $p < .001$, $\eta_p^2 = .10$, and further interacted with strategy, $F(1.93, 289.08) = 9.25$, $p < .001$, $\eta_p^2 = .06$. Follow-up simple effects analyses showed that participants asked to memorize person sources specifically rated verbal (sentence) mediators to be more effective than those asked to memorize text-type sources, $F(1, 150) = 28.42$, $p < .001$, $\eta_p^2 = .16$, whereas the rated effectiveness of imaginal mediators and rote repetition did not vary by source type, both $F \leq 1.45$. As a consequence, whereas imaginal mediators were always rated as significantly more effective than the other two strategies, all $p < .001$, verbal (sentence) mediators were rated more effective than rote repetition in the person sources conditions, $p < .001$, but not in the text-type sources conditions, $p = .242$. There was no main effect of imagery instructions, $F(1, 150) = 2.81$, $p = .096$, but a significant interaction of instructions and strategy, $F(1.92, 289.08) = 3.70$, $p = .027$, $\eta_p^2 = .02$. Although imaginal mediators were already rated the most effective strategy in the spontaneous conditions, imagery instructions significantly increased its effectiveness rating, $F(1, 150) = 11.76$, $p = .001$, $\eta_p^2 = .07$, but did not affect ratings of sentence mediators and rote repetition, both $F \leq 1.69$. No other effects were significant, all $F \leq 1.84$, $p \geq .162$. That is, there were no interactions involving age group. As evident in Table 3, strategy effectiveness ratings correlated positively with use of the respective strategy in both age groups.

3.3.3. Monitoring of strategy effects on memory

Participants' item and source memory postdictions[6] (see Table 4 for descriptives) and actual item (Pr) and source memory (ACSIM) were positively correlated for both younger [$r(77) = .61$ and .58 for item and source, respectively, both $p < .001$], and older adults [$r(78) = .62$ and .60, $p < .001$]. In two 2 (age group) × 2 (source type) × 2 (strategy instructions) ANOVA we analyzed whether postdicted item-memory and source-memory performance reflected these factors' actual effects on item and source memory. Postdictions did not reflect the observed actual item and source memory differences between age groups, $F(1, 151) = 1.79$, $p = .184$, for item memory and $F < 1$ for source memory, or between source types, $F(1, 151) = 1.35$, $p = .247$, and $F(1, 150) = 1.57$, $p = .213$. Nonetheless, postdictions accurately reflected the large actual increase in memory with instructions to generate imaginal mediators, $F(1, 151) = 21.83$, $p < .001$, $\eta_p^2 = .13$, and $F(1, 150) = 19.24$, $p < .001$, $\eta_p^2 = .14$. No other effects were significant, largest $F(1, 151) = 2.98$, $p = .087$, for the age group × source type interaction on item-memory postdictions. These results suggest that participants of both age groups were able to monitor strategy effects on item and source memory. Correlations between strategy use and postdicted item and source memory were, however, mostly nonsignificant in younger adults whereas in older adults significant positive correlations emerged (see Table 3).

4. Discussion

Our results show that instructions to use imaginal mediators improve source memory by about 10% independent of participant age and source type (abstract text-type vs concrete person sources). Participants of both age groups recognized the effectiveness of imaginal and (less so) sentence mediators for source memory and, importantly, experienced the source-monitoring task as less difficult when using mediators. Thereby, our results replicate and extend our previous investigation on mediator-based strategies in source memory (Kuhlmann & Touron, 2012) and demonstrate that mediator-based strategies bring both objective and subjective benefits to younger and older adults.

Importantly, the benefits of mediator-based strategies are not just confined to improving source memory but simultaneously improve memory for the individual items themselves. This mirrors effects from the noun-pair paradigm in which mediator-based strategies likewise improve memory for the noun–noun associations as well as for the individual nouns (Naveh-Benjamin et al., 2007). Nonetheless, the strong mediator effects on item memory cannot explain their effects observed on source memory for which we computed ACSIM, an empirical measure of source memory that does not vary with item memory (Murnane & Bayen, 1996). More specifically, because ACSIM is computed for recognized items only, item-recognition increases from the spontaneous to the instructed conditions do not likewise increase ACSIM. Instead, ACSIM uniquely depends on memory for the specific item–source association (but see Footnote 3). Thus, it can be concluded that mediators improve memory for the item–source association (cf. Kuhlmann & Touron, 2012). But not only is the source better remembered for a few recognized items when generating mediators but, additionally, a larger number of items is better remembered (and then sourced). Both benefits of mediator-based strategies (to item and source memory) appear to be preserved in healthy aging but it should be noted that performance was close to ceiling for the person sources in younger adults (especially in source memory), which may obscure subtle age-related deficits in instruction effects. Likewise, power was not satisfactory to detect small age-group effects. However, these findings replicate two previous studies from our lab in which performance was off-ceiling (Kuhlmann & Touron, 2012) and differential instructional benefits between age groups were detected with comparable sample sizes in noun-pair learning (Naveh-Benjamin et al., 2007; note that the instruction benefit was greater in older adults in this study).

Despite their benefits, both younger and older adults spontaneously used mediator-based strategies on only about half of the trials and thus showed suboptimal (item and source) memory performance when not instructed to use mediators. It remains unclear why participants do not optimally use this effective strategy spontaneously. The instructed conditions demonstrate that participants of both age groups could, on average, generate mediators for about 80% of the to-be-studied word–source pairs. The post-task ratings further suggest that participants were aware of the effectiveness of imaginal mediators in the spontaneous conditions, although imagery instructions further increased effectiveness estimates. However, it must be considered that we collected these effectiveness ratings *after* task experience. Research on noun-pair learning has found that younger and older adults are relatively unaware of mediator benefits *before* task experience (e.g., Hertzog et al., 2012). This might similarly apply here and thus even without further instruction there may be increases in mediator use in a following second study phase. Nonetheless, this means that at least in typical source-monitoring studies with only one study-test cycle, uninstructed participants make fairly little use of mediators. Even after task experience, participants of both age groups underestimated the effectiveness of verbal (sentence) mediators, especially for the text-type sources for which sentence mediators were incorrectly rated no more effective than repetition. Younger and older adults' underuse of mediator strategies when asked to memorize item–source pairs is unfortunate not only because they perform less well on the task than they could but also because, according to their subjective reports, more frequent use of mediators substantially eased the task.

Replicating our previous study (Kuhlmann & Touron, 2012) there were no age-group differences in average use of mediators on either source-monitoring task. A limitation of our current experiment, however, is that the employed source-monitoring tasks produced rather small age-group differences in item and source memory. This is likely due to (a combination of) the long encoding time, the highly concrete/imaginable word material, and the perhaps fairly young older-adult sample. However, in Kuhlmann and Touron (2012), we similarly observed no age-group differences in mediator-based strategy use on more difficult, faster-paced source-monitoring tasks producing larger age-group differences (especially in Experiment 2b, which also recruited an older sample). Additionally, it must be considered that the group sizes did not allow for the detection of subtle age-group differences in strategy use. However, such rather subtle differences could not account for much of the age-related source-memory deficit and our design nonetheless picked up on age-group differences in mediator preferences (see below).

Interestingly, our novel subjective post-task estimates suggest that this lack of age-group differences in mediator production occurred even though the older adults rated mediator strategies as less effective for improving memory than younger adults. This outcome is in line with reports of reduced memory control beliefs in older adults (Lachman, 1991, 2006), which may sometimes render them less likely to spontaneously use encoding strategies (Lachman & Andreoletti, 2006). Therefore, it is possible that the lower effectiveness beliefs render older adults less likely to produce mediators when production becomes more challenging (cf., Bottiroli et al., 2010; Touron & Hertzog, 2004). Notably, however, older adults' ratings were lower for the non-mediator strategy repetition as well and, importantly, there were no age-group differences in the relative rank order of strategy effectiveness. That is, older adults recognized that mediators were more effective for source memory than repetition in line with other reports of spared relative monitoring of strategy effectiveness in old age (Dunlosky & Hertzog, 2000; but see; Hertzog et al., 2012). Given the overall lower effectiveness ratings though, it may be useful to also address memory controllability and strategy effectiveness in intervention studies training mediator strategies for source encoding in older adults (cf., West et al., 2008).

Despite the overall comparability of mediator use, there were interesting age-group differences in mediator-type preferences: although both age groups generally used more image than sentence mediators, older adults generated more images than younger adults, who in turn generated sentences for many trials (more than older adults), especially for the person sources. The finding that older adults generated more imaginal mediators than younger adults conflicts with some earlier reports about difficulty with and even reluctance to use imagery in older adults (Bruyer & Scailquin, 2000; Hulicka et al., 1967; Verhaeghen & Marcoen, 1994) but is in line with several other studies documenting preserved generation of imaginal mediators (Dunlosky & Hertzog, 2001; Dunlosky et al., 2005). Interestingly, the post-task questionnaire revealed that older adults (just like younger adults) experienced the source-monitoring task as easier in the imagery-instructed conditions, in which they generated many images.

The occurrence of such age-group differences in mediator-type preferences, even when one type of mediator was instructed, has important implications for neuropsychological studies on aging and source memory because imagery-based versus verbal encoding strategies are associated with differential patterns of brain activation. More specifically, the generation of imaginal mediators is associated with increased activation in the left middle occipital gyrus, the lingual gyrus, and the left precuneus (Leshikar et al., 2012). Verbal-mediator (sentence) generation is associated with activity in left inferior frontal and lateral temporal regions (Leshikar, Gutchess, Hebrank, Sutton, & Park, 2010), although these may also more generally indicate relational processing and thus be activated during both imaginal and sentence mediator generation (Leshikar et al., 2012). Given this, it seems crucial for neuropsychological studies on aging and source-monitoring to assess and control for strategy use (cf., Kirchhoff, 2009).

The results further support our hypotheses that sources differ in the extent to which they afford mediator generation. Somewhat surprisingly, and contrary to our prediction, however, the (from our view) more concrete person sources did not generally increase mediator use but rather specifically increased sentence use (both spontaneous and instructed), especially for younger adults. This is also reflected in higher effectiveness ratings for verbal mediators for the person than text-type sources. In hindsight, this differential preference for verbal mediators by source type might be explained with the fact that the text-type manipulation, despite being seemingly more abstract than the person sources, is a perceptual manipulation and thus may specifically afford image use. Indeed, one can directly apply the perceptual qualities of the text types (wavy and thin for italic, straight and fat/wide for bold) to an image whereas imaging a stranger (albeit presented by a picture) in different situations may be more perceptually complex and difficult. Overall then, these findings support our original hypothesis that some sources may afford mediator generation (at least a particular type of mediator) more than others.

Concurrently, source memory was better for person than text-type sources. There is a lack of research experimentally comparing different types of (external) sources. Boywitt and Meiser (2012) report better incidental source memory for intrinsic than extrinsic source features but no differences in intentional source memory (as examined here). Importantly, meta-analyses reveal that age-related differences in source memory vary by source type (Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995), but of course this must be interpreted with caution given comparisons across different experiments. In the present study, source-type effects on strategy use and source memory were comparable between younger and older participants. However, it is still plausible that other source-type manipulations may yield differential effects across age groups. In the current and our previous studies, participants of both age groups were quite creative in generating mediators for external sources, such as text type, persons, and spatial positions but there are many other source types to be explored. Further, an open question is to what extent strategies affect memory for different internal sources and reality monitoring (i.e., an internal vs external source) and whether there are age-group differences in the ability to use mediators to improve these other types of source monitoring.

We further attempted to gain some insight into the effectiveness of imaginal versus verbal mediators, particularly for source memory. However, this proved difficult because participants mostly used one type of mediator, thus providing little opportunity to measure their memory performance under the other type of mediator. Thus, we relied on correlational analyses, which may confound strategy use with participant characteristics. However, participant characteristics did not systematically predict strategy use in the present study. Nonetheless, the ideal comparison might be a within-subject comparison of imaginal-mediator instructions to verbal-mediator instructions (cf., Siegler & Lemaire, 1997) but the current study did not include two instruction groups. Notably, our imagery-instructed conditions suggest experimental control of the type of mediator used is somewhat difficult, as verbal-mediator generation seemed to respond to the instructions as well. This reflects that encoding strategy generation is a creative act. The correlational analyses suggest a similar effectiveness of imaginal and verbal mediators and this was further confirmed by within-subjects comparisons in those (few) participants who used both imaginal and verbal mediators. Thus, the current data suggest that imaginal and verbal mediators are comparably effective for improving source memory.

At least for external sources, the repeated finding of preserved spontaneous mediator use in older adults has important implications for the interpretation of the well-documented age-related deficit in memory for external sources (Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995): This appears to reflect “true” age-related memory differences, rather than only strategic differences. Even when older adults generated a mediator they were less able to later remember the item–source association. This mirrors studies on noun-pair memory, where large age-related differences in cued recall remain even when older adults generate good mediators at encoding (Dunlosky & Hertzog, 1998, 2001; Dunlosky et al., 2005). Dunlosky et al. (2005) found that this remaining deficit may in part be due to older adults' deficits in (a) retrieving the mediators formed during study at test (another indication of the associative deficit) and (b) properly decoding retrieved mediators. However, in their study, age-group differences in associative memory remained (albeit significantly reduced) even after controlling for these potential strategic deficits. All in all, these results converge with the notion of an associative or memory binding deficit in older adults (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000) but at the same time attest that associative-memory improvement remains possible. In line with this, the incidental associative memory measure (memory for the digit-symbol associations in the digit-symbol substitution task) fully mediated age-group differences in source memory, independent of mediator use.

Our findings and our strategy-assessment and strategy-instruction methodology may have important implications for research interested in determining the neural basis of source memory, particular item–source binding. As reviewed by Mitchell and Johnson (2009) and cited earlier, there has been great interest in determining the neurological basis of binding/associative memory processes, which are believed to take place in the hippocampus. It should be helpful for this endeavor to separate trials with high binding activity at encoding (i.e., generation of mediators) from trials where little to no binding was achieved (i.e., mere repetition or no/word-only strategies). As we showed, quite brief strategy instructions without training successfully increase mediator generation in younger and older participants. Thus, mediator use can be instructed between or within (but one must be wary of sequential effects; Hinault et al., 2016) for this purpose. Either way, it appears advisable to assess item-level strategy reports because despite our data suggesting quite high compliance participants will not successfully generate a mediator on all instructed trials and, as our results reveal, it may be difficult to induce use of one specific type of mediator for all participants. Fortunately, such strategy reports can be assessed retrospectively, and thus outside the scanner, with reasonable validity for both younger and older adults (Dunlosky & Hertzog, 2001; Kuhlmann & Touron, 2012). Taking item-wise strategy reports and interindividual differences in strategy use into account will also be useful for better understanding the role of frontal-lobe areas in source encoding, which may be crucial for the initiation of mediator generation during encoding (Kirchhoff, 2009). Finally, it will be interesting to compare younger and older adults' brain activity when generating imaginal or sentence mediators. It is quite plausible that the observed similar behavioral effects are accompanied by differential brain activity. Increased bilateral activation (Cabeza, 2002) as well as recruitment of additional brain regions (Reuter-Lorenz, 2002) has been observed in older adults' processing on memory tasks. As Mitchell and Johnson (2009) point out, “it is still unclear whether the added activity represents the recruitment of additional areas to do the same processing or the recruitment of different processes to do the same task” (p. 659). Testing whether such differences in brain activity persist even when examining trials for which younger and older adults use the same strategy could help answer this important question.

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[1] Inclusion of this participant would not change the main pattern of results but this younger participants' extremely poor source-memory performance renders the age-group difference in source memory only marginal (p = .057).

[2] Despite random assignment, there were significant differences between the older-adult conditions in the processing speed measure (i.e., DS completion), $F(3, 79) = 3.39$, $p = .022$, $\eta_p^2 = .12$, and in average years of formal education, $F(3, 79) = 2.87$, $p = .042$, $\eta_p^2 = .10$. Follow-up tests revealed that these were due to older adults in the spontaneous text-type condition significantly outperforming those in the two person conditions. The imagery-instructed text-type condition fell in between and did not significantly differ from the other three conditions. At large, these measures were not predictive of source memory or strategy use (with the exception of DS completion predicting verbal mediator use in older adults; see Table 3). The older-adult conditions did not differ in terms of any of the other measures, all $p \geq .220$, including the incidental associative-memory measure from the digit-symbol pairings (p = .372), which was predictive of source memory (see Section 3.2). In order to ensure that these chance differences between older-adult groups did not affect the results, we confirmed that all results held when processing speed and years of education were controlled for (z-standardized within age groups as to not eliminate age-group differences related to these measures). The four younger-adult conditions did not differ on any of the characteristics presented in Table 1, all $p \geq .246$.

[3] ACSIM still confounds source memory and source guessing processes (Murnane & Bayen, 1996). Therefore, we also analyzed the data with the two high-threshold multinomial model of source monitoring (Bayen, Murnane, & Erdfelder, 1996) and confirmed that participants of both age groups did not have systematic biases in guessing between the two text types or persons, rendering the interpretation of ACSIM as a measure of source memory unproblematic. Because the multinomial modeling method does not readily allow for testing full factorial designs (esp. with regards to disordinal interactions), we preferred to present analyses based on ACSIM.

[4] An alternative way is to compare memory under mediator versus no-mediator strategies within participants, as done in Kuhlmann and Touron (2012). However, 50% of younger adults and 43% of older adults in the instructed conditions used mediator-based strategies on more than 90% of the word–source pairs, thus allowing no reliable estimate of their memory performance when using no mediator. A significant main effect of the within-subjects strategy factor in the spontaneous conditions demonstrated better item [M_{mediator} = .79 (*SE* = .02); $M_{\text{non-mediator}}$ = .50 (*SE* = .03)] and source memory [M_{mediator} = .82 (*SE* = .03); $M_{\text{non-mediator}}$ = .75 (*SE* = .03)] on mediator-strategy trials, $F(1, 55) = 75.56$, $p < .001$, $\eta_p^2 = .57$, and $F(1, 53) = 4.26$, $p = .044$, $\eta_p^2 = .07$, respectively. The small age-group differences (older < younger adults) were only marginal in these analyses, $F(1, 55) = 3.84$, $p = .055$, $\eta_p^2 = .06$, and $F(1, 53) = 2.92$, $p = .093$, $\eta_p^2 = .05$, due to the reduced power (i.e., smaller *n*s). Importantly, strategy and age group did not interact, both $F < 1$, suggesting similar strategy-effects in younger and older adults [mean improvement computed as performance on mediator trials minus on non-mediator trials was .24 (*SE* = .04) compared to .32 (*SE* = .04) and .10 (*SE* = .03) compared to .07 (*SE* = .03) for younger compared to older adults on item and source memory, respectively]. Source type had a main effect on item memory (better item memory when the sources were text types), $F(1,55) = 4.72$, $p = .043$, $\eta_p^2 = .07$, but not on source memory, $F < 1$ (suggesting that differences in strategy use explain the source-type effects in the overall analysis of source memory). Importantly, there were no significant interactions involving source type on either memory measure, indicating that mediator-based strategies were equally effective for both examined source types. We further attempted to conduct a within-subject analysis by mediator analysis but this proved even more difficult because most participants used one such mediator-type exclusively. Such a within-subjects comparison, based on only 49 younger and 25 older adults (across all conditions), suggested no difference between imaginal and verbal mediators in terms of Pr [younger adults: M_{imaginal} = .88 (*SE* = .03), M_{verbal} = .89 (*SE* = .03); older adults: M_{imaginal} = .78 (*SE* = .04), M_{verbal} = .77 (*SE* = .04)] and ACSIM [younger adults: M_{imaginal} = .91 (*SE* = .02) and M_{verbal} = .92 (*SE* = .03); older adults: M_{imaginal} = .88 (*SE* = .03) and M_{verbal} = .84 (*SE* = .04)], all $F < 1$.

[5] Strategy effectiveness ratings are missing for one older adult in the imagery-instructed person sources condition.

[6] This source-memory postdiction was missing for one older adult in the imagery-instructed concrete-sources condition. Participants were instructed to estimate for how many of the total number of words they estimated to have recognized they correctly attributed the source. A few participants, however, named a larger number of words sourced correctly than of words recognized resulting in proportions larger than 1. In these cases, the source-memory postdiction was set to the maximum (1.0).