Strategy combination during execution of memory strategies in young and older adults

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Abstract:

The present study investigated whether people can combine two memory strategies to encode pairs of words more efficiently than with a single strategy, and age-related differences in such strategy combination. Young and older adults were asked to encode pairs of words (e.g., *satellite-tunnel*). For each item, participants were told to use either the interactive-imagery strategy (e.g., mentally visualising the two words and making them interact), the sentence-generation strategy (i.e., generate a sentence linking the two words), or with strategy combination (i.e., generating a sentence while mentally visualising it). Participants obtained better recall performance on items encoded with strategy combination than on items encoded with interactive-imagery or sentence-generation strategies. Moreover, we found age-related decline in such strategy combination. These findings have important implications to further our understanding of execution of memory strategies, and suggest that strategy combination occurs in a variety of cognitive domains.

Keywords: Aging | memory | paired associate learning | strategy | strategy combination

Article:

The present study investigates strategic aspects of episodic memory. One important question regarding episodic memory is what factors determine individuals' performance. Also crucial is to characterise age-related changes in episodic memory. Research adopting a strategy perspective revealed that individuals use several memory strategies, and that recall performance is influenced by whether people identify and use the most effective strategy (see Hertzog & Dunlosky, 2004; Lemaire, 2015, 2016 for reviews). A strategy can be defined as "a procedure or a set of procedures for achieving a higher level goal or task" (Lemaire & Reder, 1999, p. 365). In older adults, decline in memory performance is most often observed relative to young adults. In addition, older adults use memory strategies less effectively and less adaptively than young

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adults (e.g., Angel, Fay, Bouazzaoui, Granjon, & Isingrini, 2009; Angel, Fay, Bouazzaoui, & Isingrini, 2010, 2011; Bailey, Dunlosky, & Hertzog, 2009; Bouazzaoui et al., 2010; Dunlosky & Connor, 1997; Dunlosky & Hertzog, 1997, 1998, 2001; Frank, Touron, & Hertzgo, 2013; Hayes, Kelly, & Smith, 2013; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005; Onyper, Hoyer, & Cerella, 2008; Souchay & Isingrini, 2004; Taconnat et al., 2006, 2007, 2009; Tournier & Postal, 2011; Touron & Hertzog, 2004). Indeed, older adults were found to take more time and to make more mistakes than young adults while executing strategies. Moreover, the better strategy (i.e., the strategy that yields the best performance) is less often selected by older than by young adults. Of major interest is to determine if, as it has been previously observed in other cognitive domains (Hinault, Dufau, & Lemaire, 2014; Hinault, Tiberghien, & Lemaire, 2015), memory strategies can be combined together to improve performance. The present study contributes to this issue by investigating whether encoding of items is improved when using simultaneously two memory strategies, and age-related differences in such strategy combination.

To encode pairs of words (e.g., *satellite-tunnel*), participants can rely on the rote-repetition strategy (i.e., continuously repeating the words), the interactive-imagery strategy (i.e., mentally visualising the two words and making them interact; e.g., a satellite in a tunnel), or the sentence-generation strategy (i.e., generate a sentence linking the two words; e.g., “the satellite is in the tunnel”). Both the interactive-imagery strategy and the sentencegeneration strategy involve the formation of a mediator leading to better performance relative to using no strategy or to using no-mediator strategies, like the rote-repetition strategy. A mediator can be defined as a way to bind words together, in a sentence or in a mental image (e.g., visualising a satellite in a tunnel; e.g., Richardson, 1978, 1998). The interactive-imagery strategy has been found to be used more often than the sentence-generation strategy (e.g., Dunlosky & Hertzog, 1998). However, similar performance has been observed between the two strategies (e.g., Tournier & Postal, 2011). With aging, although differences between young and older adults are sometimes found (e.g., Dunlosky & Hertzog, 2001), older adults usually know and use as many memory strategies as young adults (e.g., Dixon & Hultsch, 1983; Dunlosky & Hertzog, 1998; Hertzog & Hultsch, 2000; Kuhlmann & Touron, 2012; Loewen, Shaw, & Craik, 1990). However, older adults have been found to show poorer recall performance compared to young adults (e.g., Dunlosky & Hertzog, 2001; Hertzog, Price, & Dunlosky, 2012; Tournier & Postal, 2011). Dunlosky, Hertzog, and Powell-Moman (2005; see also Naveh-Benjamin, Guez, & Sorek, 2007) revealed that older adults were selectively impaired in retrieval of mediators, and regression analyses revealed that this decline accounted for a substantial proportion of age-related variance in recall performance. This age-related decline was found to be larger for the interactive-imagery strategy than for the sentence-construction strategy (Craik & Dirkx, 1992; Dror & Kosslyn, 1994; Kemps & Newson, 2005).

One of the goals of the present study was to investigate strategy combination effects in episodic memory. These effects were found in another cognitive domain, in arithmetic strategies, but were never studied in memory. In arithmetic, participants can rely on rule-violation checking strategies to quickly determine that a proposed answer (e.g., $5 \times 31 = 158$) is false (Krueger & Hallford, 1984; Krueger, 1986; Lemaire & Fayol, 1995; Lemaire & Reder, 1999; Masse & Lemaire, 2001; Siegler & Lemaire, 1997). Recently, Hinault et al. (2014; see also Hinault et al., 2015) found that participants have better performance when both the five rule (i.e., products of problems including five as an operand end with either five or zero; e.g., $5 \times 14 = 70$) and the parity rule (i.e., when at least one of the two operands is even, the product is also even; otherwise the product is odd; e.g., 4 × 13 = 51) were violated on a given problem, relative to when a proposed equation violated only the five rule or only the parity rule. Hinault et al. (2015) interpreted this finding as reflecting the combination of both rule-violation checking strategies into a single, more efficient strategy. Strategy combination consisted of determining whether (a) an equation with five and an even operand had a product that ends with zero, and (b) an equation with five and an odd operand had a product that ends with five. Age-related differences were observed regarding strategy combination The authors found that, relative to young adults, older adults showed a reduced benefit of rejecting two-rule violation problems relative to one-rule violation problems. These reduced benefits in older adults compared to young adults have been interpreted as reflecting less efficient and/or less systematic use of strategy combination with age.

Unknown is whether this strategy combination phenomenon is restricted to the specific domain of arithmetic or if it exists in many cognitive domains. To determine this, the present work investigated this strategy combination phenomenon in another domain, episodic memory, where previous research established that participants use multiple strategies (e.g., Hertzog & Dunlosky, 2004; Lemaire, 2015, 2016). The present study pursued two main goals. First, we tested strategy combination in the memory domain. Second, we investigated whether strategy combination declines with age when participants encode pairs of words for future recall. If strategy combination exists in memory, we expected to find strategy combination when participants memorise pairs of words under a two-strategy condition than under a one-strategy condition. This would be seen in better recall performance when participants are cued to combine the interactiveimagery strategy and the sentence-generation strategy compared to when only one memory strategy was cued. Moreover, one important goal in this study was to determine whether less efficient strategy combination with age, as previously observed in arithmetic, is also found in memory. Given previous studies about age-related differences in memory strategies (e.g., Dunlosky & Hertzog, 2001; Hertzog et al., 2012; Tournier & Postal, 2011), we expected older adults to show less efficient strategy processing and strategy combination relative to young adults. We expected aging effects on strategy combination, with older adults not showing greater recall performance with strategy combination relative to with the interactiveimagery strategy and/or the sentence-generation strategy.

METHOD

Participants

Thirty young adults (range 20–29 years, *M* = 24.6 years, SD = 2.3) and 30 older adults (range 65–86 years, *M* = 73.6 years, SD = 5.3) participated in the experiment. All older adults had a Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) score of 27 or more. Young and older adults were similar in years of education (respectively, *M* = 15.73, SD = 2.39 and *M* = 14.83, SD = 1.86; $F < 3.0$) and in verbal fluency (respectively, *M* = 23.00, SD = 2.16 and *M* = 24.00, SD = 6.15, $F < 1.0$), measured by the Mill-Hill vocabulary test (Deltour, 1993).

Stimuli

All participants studied a list of 30 pairs of words. Following previous works (e.g., Hertzog & Touron, 2011; Touron & Hertzog, 2004; Tournier & Postal, 2011), we used pairs of words to provide cues that facilitate recall, especially in older adults. The words were derived from a list of French words taken from Bonin et al. (2003). Pairs of words were cued, in equal proportions, with either the interactive-imagery strategy, the sentence-generation strategy, or with strategy combination. This resulted in 10 pairs of words for each strategy. Pairs of words did not differ between strategy cues in values of imagery, mean subjective frequency, and emotional valence (*Fs* < 1). The associative values of words were controlled between pairs of words and across strategies based on the French norms of associative values of Ferrand and Alario (1998) and Ferrand (2001). Pairs of words with high strengths of association were not used.

Procedure and design

Participants were first told that they were going to memorise 30 pairs of words (e.g., *satellite-tunnel*). Then, they were explained that a cue would indicate which strategy to use to encode each pair of words. Only two memory strategies and strategy combination were allowed, and participants were instructed, in a jargon-free manner, how to execute these strategies. The interactive-imagery strategy was described as creating a mental image linking the words, preferably in making items interact. The sentence-generation strategy was described as linking the words within one sentence. Strategy combination was described as linking words within a same sentence, while mentally visualising the scene depicted by this sentence. Practice included nine pairs of words, three pairs to be encoded with the interactive-imagery strategy, three with the sentence-generation strategy, and three with strategy combination. After the oral recall of practice items, the experimenter ensured that participants understood each strategy, knew how to implement them, and encouraged participants to ask questions or details. Then, the experimental memory task started. Strategies were cued in a random order. The experimental stimuli were presented in 48-point bold courier font (black colour) in the centre of a 14-inch computer screen controlled by an HP EliteBook. The experiment was controlled with the E-Prime software (Psychology Software Tools, Pittsburgh, PA).

Participants were tested individually. Every pair of words was preceded by a cued strategy displayed for two seconds. Sentence-generation and interactiveimagery strategies were cued with the words “sentence” and “image”, respectively. Strategy combination was cued with the word “combination”. The cue then remained on the top right corner of the screen, together with pairs of words. Following previous works (e.g., Hertzog et al., 2012), pairs of words were displayed in the centre of the screen at a rate of eight seconds in older adults and six seconds in young adults. This was done to ensure that older adults would not have floor recall performance, given cognitive slowing with aging (Salthouse, 1996). The experimenter monitored correct execution of the sentence-generation strategy and strategy combination by the verbal output (i.e., sentence) of the participants during encoding. Following previous studies (e.g., Uittenhove, Burger, Taconnat, & Lemaire, 2015), the experimenter asked participants at the end of the experiment to provide two of the mental images they constructed during the experiment. Three seconds between pairs were included to limit interference in the learning of different pairs. At the end of the list, recency effects in subsequent recall were eliminated by asking participants to execute a letter-judgment task (i.e., indicating whether a series of letters included both vowels and consonants or included only one type of letters; e.g., aevc) for 30 seconds. Immediately after this letter-judgment task, a cued recall was proposed: The first word of a pair (e.g., *satellite – ???*) was presented on the computer screen for a maximum of 15 seconds, and participants had to verbally recall the second word (within 15 seconds). Each pair appeared in a new order, different from the order in which it was encoded.

RESULTS

To investigate strategy combination in memory, and aging effects therein, mean number of correctly recalled words (Table 1), omission errors (i.e., participants did not recall any words), intrusion errors (i.e., participants recalled a word that was not previously studied), and recombination errors (i.e., participants recalled a studied word that was paired with a word other than the cued word) were analysed using 2 (age: young adults, older adults) × 3 (strategy: interactive-imagery, sentence-generation, strategy combination) mixed-design ANOVAs, with age as the only between-participants factor. All data were log-transformed to minimise the effects of skewness and to ensure that age differences cannot be attributed to different baselines (e.g., Faust, Balota, Spieler, & Ferraro, 1999), but untransformed values are reported for the sake of clarity.

Older adults recalled significantly fewer words than young adults (2.8 vs. 5.5 words), $F(1,58) = 30.01$, $MSe = 0.08$, $\eta_p^2 = .34$, as revealed by a main effect of age. Moreover, the main effect of strategy was significant ($F(2,116) = 16.54$, $MSe = 0.01$, $\eta_p^2 = .22$), showing that recall performance differed as a function of the strategy cued during encoding. Planned comparisons revealed that participants were equally effective in recalling words encoded with either the interactive-imagery or the sentence-generation strategy (3.6 vs. 3.9 words; $F < 3.0$). Most importantly, strategy combination (5.1 words) yielded significantly better recall than the interactive-imagery strategy ($F(1,59) = 40.10$, $MSe = 0.04$, $\eta_p^2 = .41$) and the sentence-generation strategy ($F(1,59) = 12.47$, $MSe = 0.01$, $\eta_p^2 = .17$). Moreover, the Age × Strategy interaction was significant ($F(2,116) = 3.38$, $MSe = 0.01$, $\eta_p^2 = .06$). Planned subgroup analyses in young and in older adults revealed several interesting findings.

In young adults, the main effect of strategy was significant, $F(2,58) = 12.03$, $MSe = 0.01$, $\eta_p^2 = .29$. Planned comparisons showed that participants were equally effective in recalling words encoded with either the interactive-imagery strategy or the sentence-generation strategy (5.1 vs. 4.9 words; $F < 1.0$). Most importantly, strategy combination (6.5 words) yielded significantly better recall performance than the interactive-imagery strategy ($F(1,29) = 28.51$, $MSe = 0.02$, $\eta_p^2 = .50$) and the sentence-generation strategy ($F(1,29) = 19.18$, $MSe = 0.02$, $\eta_p^2 = .40$). In older adults, the main effect of strategy was also significant, $F(2,58) = 9.32$, $MSe = 0.02$, $\eta_p^2 = .24$. Planned comparisons revealed a significant difference between the interactive-imagery strategy and the sentence-generation strategy (2.0 vs. 2.8 words; $F(1,29) = 6.15$, $MSe = 0.02$, $\eta_p^2 = .18$). Interestingly, while strategy combination (3.6 words) yielded significantly better recall performance than the interactive-imagery strategy $F(1,29) = 21.88$, $MSe = 0.06$, $\eta_p^2 = .43$), no differences were found relative to the sentence-generation strategy ($F < 3.0$), suggesting that older adults did not fully benefit from strategy combination, in contrast to young adults.

Table 1. Young and older adults' mean number of correctly recalled words, mean number of omission errors, mean number of intrusion errors, and mean number of recuperation errors, with SEM, for interactive-imagery strategy, sentence-generation strategy, and strategy combination.

Strategy	Young adults	Older adults	Means
Mean numbers of correctly recalled words			
Interactive-imagery	5.1 (0.4)	2.0 (0.4)	3.6 (0.3)
Sentence-generation	4.9 (0.4)	2.8 (0.4)	3.9 (0.3)
Strategy combination	6.5 (0.4)	3.6 (0.4)	5.1 (0.3)
Means	5.5 (0.4)	2.8 (0.4)	4.2 (0.3)
Mean numbers of omission errors			
Interactive-imagery	3.3 (0.4)	7.0 (0.5)	5.2 (0.4)
Sentence-generation	3.7 (0.4)	6.1 (0.4)	4.9 (0.3)
Strategy combination	2.9 (0.4)	5.4 (0.4)	4.2 (0.3)
Means	3.3 (0.4)	6.2 (0.4)	4.8 (0.3)
Mean numbers of intrusion errors			
Interactive-imagery	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)
Sentence-generation	0.8 (0.2)	0.7 (0.2)	0.7 (0.1)
Strategy combination	0.6 (0.1)	0.7 (0.1)	0.6 (0.1)
Means	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)
Mean numbers of recuperation errors			
Interactive-imagery	1.2 (0.2)	0.5 (0.1)	0.8 (0.1)
Sentence-generation	0.4 (0.1)	0.3 (0.1)	0.3 (0.1)
Strategy combination	0.4 (0.1)	0.3 (0.1)	0.3 (0.1)
Means	0.6 (0.1)	0.3 (0.1)	0.5 (0.1)

Note: Interactive-imagery strategy: linking pairs of words within a same mental image; sentence-generation strategy: linking pairs of words within a same sentence; strategy combination: making a mental image of a generated sentence; mean numbers of omission errors: mean numbers of errors in which participants did not recall any words; mean numbers of intrusion errors: mean numbers of errors in which participants recalled a word that was not previously studied; mean numbers of recuperation errors: mean numbers of errors in which participants recalled words that was paired with another word that the cued word.

Regarding omission errors, analyses revealed a main effect of age, $F(1,58) = 33.96$, $MSe = 0.07$, $\eta_p^2 = .37$. Older adults made more errors than young adults (6.2 vs. 3.3 errors). Also, a main effect of strategy was found, $F(2,116) = 4.84$, $MSe = 0.01$, $\eta_p^2 = .08$. Planned comparisons showed that fewer omission errors were committed when strategy combination was used (4.2 errors) as compared to the interactive-imagery strategy (5.2 errors; $F(1,59) = 12.81$, $MSe = 0.01$, $\eta_p^2 = .18$) or to the sentence-generation strategy (4.9 errors; $F(1,59) = 6.19$, $MSe = 0.02$, $\eta_p^2 = .10$). However, participants did not differ on omission errors between the interactive-imagery strategy and the sentence-generation strategy ($F < 1.0$). The Age × Strategy interaction was not significant ($F < 1.5$). Analyses on recombination errors showed a main effect of strategy ($F(2,116) = 7.09$, $MSe = 0.01$, $\eta_p^2 = .11$). Planned comparisons showed that more recombination errors were committed when the interactive-imagery strategy was used (0.8 errors) relative to the sentence-generation strategy (0.3 errors; $F(1,59) = 11.73$, $MSe = 0.01$, $\eta_p^2 = .17$) or strategy combination (0.3 errors; $F(1,59) = 5.19$, $MSe = 0.01$, $\eta_p^2 = .08$). However, participants did not differ on recombination errors between the sentence-generation strategy and strategy combination ($F < 1.5$). Moreover, the Age × Strategy interaction was marginally significant

($F(2,116) = 2.88$, $p = 0.06$, $MSe = 5.17$, $\eta_p^2 = .05$). Subgroup analyses revealed that the main effect of strategy was significant in young adults ($F(2,58) = 6.65$, $MSe = 0.01$, $\eta_p^2 = .19$) but not in older adults ($F < 1.0$). In young adults, more recombination errors were committed when pairs of words were encoded with the interactive-imagery strategy (1.2 errors) than with the sentence-generation strategy (0.4 errors; $F(1,29) = 9.57$, $MSe = 0.01$, $\eta_p^2 = .25$) or with strategy combination (0.4 errors; $F(1,29) = 5.71$, $MSe = 0.01$, $\eta_p^2 = .16$). No differences were found between the sentence-generation strategy and strategy combination ($F < 1.5$). Analyses on intrusion errors did not reveal any main or interaction effects ($F < 1$).

DISCUSSION

The present study revealed several original findings on aging and strategic variations in the context of memory strategies. Our results showed better memory performance in young adults than in older adults, replicating previous findings in memory (e.g., Dunlosky & Hertzog, 2001; Hertzog et al., 2012; Tournier & Postal, 2011). Furthermore, differences in recombination errors between the interactive-imagery strategy and the sentence-generation strategy suggest that, although these two strategies yield similar rates of correct recall, memory retrieval may be less specific for the interactive-imagery strategy than for the sentence-generation strategy. Most originally, our results revealed that young adults showed better recall performance when word pairs were encoded with a combination of both interactive-imagery and sentence-generation strategies than when a single memory strategy was used. Moreover, we found age-related differences in strategy combination, as older adults did not show better recall performance with strategy combination than with the sentence-generation strategy

The present findings revealed that combining the interactive-imagery strategy and the sentence-generation strategy to encode pairs of words yielded better memory performance than using a single memory strategy. Thus, results are inconsistent with the use of a single strategy to encode items cued with strategy combination. It seems that strategy combination is a general characteristic of strategic processing, as it was observed in both arithmetic (Hinault et al., 2014, 2015) and memory domains. Encoding pairs of words with both sentence-generation and interactive-imagery strategies was described to participants as constructing a sentence while visualising it. This strategy combination may lead to a deeper encoding, subsequently leading to better recall performance.

In older adults, recall performance was poorer when asked to use the interactive-imagery strategy than the sentence-generation strategy. This finding is consistent with previous studies showing that mental-imaging abilities decline during aging (e.g., Craik & Dirkx, 1992; Dror & Kosslyn, 1994; Kemps & Newson, 2005), and that older adults produce less specific images (e.g., Palladino & De Beni, 2003). Most importantly, in complete contrast with young adults, better recall performance with strategy combination than with single memory strategies was not observed. Indeed, while strategy combination yielded better recall performance than the interactive-imagery strategy, no differences were found relative to the sentence-generation strategy. However, it is important to note that instructions of strategy combination seemed to somewhat improve older adults’ performance, as recall performance with strategy combination was significantly better than with interactive-imagery strategy. To determine whether sub-groups can be observed in older adults in strategy combination abilities, we tried to distinguish older adults as a function of number of education, age, or vocabulary score, but no effects were found. Postexperimental informal debriefing suggested that mentally visualising the sentence while generating it was very demanding for older adults. Therefore, it appears that reduced benefits for strategy combination in older adults relative to young adults results from this strategy exceeding available processing resource capacities in older adults. We can also consider that, despite having more time to encode pairs of words than young adults, this duration was too short for older adults to create precise and salient mental visualisation of the scene depicted by the sentence, and to fully benefit from strategy combination. Alternatively, older adults may have been reluctant to use strategy combination even if cued to do so, as previous works revealed that metacognitive and volitional factors modulate strategy use in older adults (e.g., Frank et al., 2013; Touron & Hertzog, 2004, 2009; Touron, Swaim, & Hertzog, 2007; see Touron, 2015 for a review). Future studies will investigate whether metacognitive knowledge about strategy combination (i.e., information about the higher effectiveness of using this strategy) could influence the effects of age on strategy combination.

Before any definitive conclusions, several limitations of the current study need to be considered. First, we did not collect trial-by-trial strategy ratings from participants to ensure that the strategies were implemented as successfully in young and older adults (e.g., Hertzog & Dunlosky, 2006). Therefore, it is possible that our sample of older adults did not comply with strategy instructions as well as our sample of young adults. However, differences in recall performance as a function of the cued strategy provide converging evidence that both young and older adults complied with task requirements. It is also possible that the mixed design used in the study could have confused the older adults and prevented them from benefitting from strategy use. However, a block design may run the risk of carry-over effects of strategy use between blocks. Moreover, we may consider that the processes involved in strategy combination differ between the present study and previous studies in arithmetic, as strategy combination was explicitly cued in the present study and not in previous arithmetic studies. Future studies will test this hypothesis by contrasting one condition in which strategy combination is explicitly required to a condition in which no indications are given to participants and that verbal reports are studied. Finally, the present data, although consistent with previous findings about strategy combination, does not rule out an explanation in terms of sequential strategy use. Indeed, we can hypothesise that, in the same item, participants first used the sentence-construction strategy, and then the interactiveimagery strategy, or the opposite. Future studies manipulating encoding time and/or using electroencephalography (EEG) will aim at distinguishing these two hypotheses. In line with previous findings in arithmetic strategy combination (Hinault et al., 2014), we predict that strategy combination would result in shorter encoding times and larger EEG modulations than a sequential strategy use.

The present results revealed that memory performance can be improved when participants are asked to combine two memory strategies to encode items. With age, these processes seem less efficient, in line with fewer processing resources in older adults than in young adults (see Salthouse, 1988, for a review). Theoretically, these findings also have implications for how models of strategy use (e.g., Lovett & Anderson, 1996; Lovett & Schunn, 1999; Payne, Bettman, & Johnson, 1993; Rieskamp & Otto, 2006; Siegler & Araya, 2005) consider participants' performance in a variety of cognitive domains. Models need to provide complementary assumptions about the possibility to combine several strategies together to solve problems or to encode items.

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