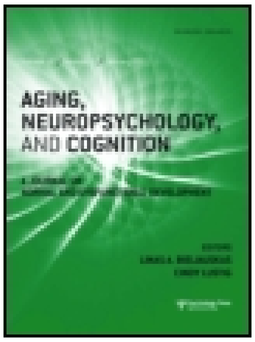

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Age-related differences in recognition in associative memory

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ABSTRACT

Aging is often accompanied by associative memory changes, although their precise nature remains unclear. This study examines how recognition of item position in the context of associative memory differs between younger and older adults. Participants studied word pairs (A–B, C–D) and were later tested with intact (A–B), reversed (D–C), recombined (A–D), and recombined and reversed (B–C) pairs. When participants were instructed to respond "Old" to both intact and reversed pairs, and "New" to recombined, and recombined and reversed pairs, older adults showed worse recognition for recombined and reversed pairs relative to younger adults (Experiment 1). This finding also emerged when flexible retrieval demands were increased by asking participants to respond "Old" *only* to intact pairs (Experiment 2). These results suggest that as conditions for flexible retrieval become more demanding, older adults may show worse recognition in associative memory tasks relative to younger adults.

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Relative to younger adults, older adults tend to perform poorly on tests of episodic memory (Hoyer & Verhaeghen, 2006) involving the encoding and conscious retrieval of contextually specific information, such as an event that occurred at a particular place and time (Tulving, 1983). There is a growing literature suggesting that age-related differences in episodic memory are characterized by deficits in memory for associative information (e.g., Chalfonte & Johnson, 1996; Fraundorf, Hourihan, Peters, & Benjamin, 2019; Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). Specifically, this literature suggests that older adults have a fundamental deficit in linking or integrating the separate elements of a to-be-remembered episode, and that this deficit leads to impairments in episodic memory (Bayen, Phelps, & Spaniol, 2000; Burke & Light, 1981; Chalfonte & Johnson, 1996; Lyle, Bloise, & Johnson, 2006; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Naveh-Benjamin, 2000; Ryan, Leung, Turk-Browne, & Hasher, 2007).

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However, other research has failed to identify differences in recognition between older and younger adults in associative memory tasks, particularly when stimuli or experimental conditions permit older adults to utilize schematic information or encoding support. For instance, Castel (2005) observed no age-related differences in associative recognition accuracy when participants were asked to learn the association between a familiar grocery product and a price consistent with prior knowledge. Similarly, other studies have leveraged schematic information at encoding (e.g., sentence generation) or provided participants with multiple study exposures and observed equivalent performance between younger and older adults (Craik, 1977, 1982; Glisky et al., 2001; Giovanello & Schacter, 2012). Thus, these results suggest that by lowering encoding and/or retrieval demands, older adults may perform on par with younger adults on tasks involving associative memory.

Here, we report the results of two experiments aimed at elucidating whether increases in retrieval demands may help to explain why in certain associative tasks older adults perform worse than younger adults, while in others they perform on par. Specifically, we sought to investigate whether recognition performance may be differentially affected by age under conditions that place high demands on retrieving the exact spatial and sequential arrangement encoded during the study episode. To that end, we employed a variation on a common experimental paradigm used to examine associative memory. In this paradigm, participants study word pairs (e.g., A–B, C–D) and then their memory is tested with intact word pairs that were previously studied (e.g., A–B) as well as conjunction word pairs consisting of two words that were previously studied but were recombined at test (e.g., A–D; Castel & Craik, 2003; Giovanello et al., 2012; Light, Patterson, Chung, & Healy, 2004; Naveh-Benjamin, 2000). In the particular variation we employed here, we manipulated different degrees of recombination of word pairs at test, as well as different criteria of what constitutes successful retrieval. The rationale for this manipulation is the following: while we often need to recognize prior occurrences of two of more stimuli (i.e., an exact reinstatement of a previously formed association), it is often equally important to be able to recognize previous occurrences in which two stimuli have been presented but re-instated in varying degrees of re-organization. After all, recognition of information is often not restricted by the exact parameters that were present at encoding. This capacity, often called “flexible retrieval” (Eichenbaum, 2001), may be incorporated into this traditional paradigm by including word pairs that are merely reversed (e.g., B–A), recombined but not reversed (e.g., A–C; B–D), and recombined and reversed (e.g., B–C; D–A).

Flexible retrieval has been studied in several contexts in the cognitive aging literature. For example, older adults are more likely than younger adults to falsely remember information that is consistent with, or related to, previously studied information, and have deficits in rejecting information that was similar to previously studied associations (Cohn, Emrich, & Moscovitch, 2008; Jacoby & Rhodes, 2006). In addition, older adults have greater difficulty switching between the use of specific recollection and more gist-based recall (Aizpurua & Koutstaal, 2010; Koutstaal, 2006). Currently, however, there is little evidence regarding the degree to which aging influences the ability to flexibly retrieve associative information, or whether there are age-based differences in recognition in associative memory tasks with varying demands on flexible retrieval.

In a previous study, Giovanello, Schnyer, and Verfaellie (2009) utilized functional magnetic resonance imaging (fMRI) to examine the neural correlates of flexible remembering and the use of position-specific information. In this study, younger adults relationally encoded unrelated word pairs (e.g., surgeon–arrow) and neural activity was compared during recognition of previously shown word pairs (surgeon–arrow; an "Intact Pair") with neural activity during recognition of previously shown, yet reversed word pairs (arrow–surgeon; a "Reversed Pair"). They found no significant difference in recognition performance for intact pairs and reversed pairs, yet there was a functional dissociation along the long axis of the hippocampus during retrieval of the two stimulus types. Specifically, anterior hippocampus showed equivalent activity during retrieval of intact and reversed pairs, while posterior hippocampal showed greater activity during intact pairs relative to reversed. In addition, retrieval-related activity in anterior hippocampus correlated significantly with the accuracy of associative recognition, while retrieval-related activity in posterior hippocampus showed no such correlation.

Building upon that study, the goal of the current study was to delineate behavioral differences in recognition of associative information during flexible retrieval in younger and older adults. Specifically, we hypothesized that as relational demands increase at retrieval, older adults would show reduced recognition performance relative to younger adults. We tested this hypothesis with two experiments. In the first experiment, participants were asked to answer "Old" to both intact (A–B) and reversed pairs (D–C), but "New" to both recombined (A–D) as well as recombined and reversed pairs (B–C). Although we expected to see no difference in recognition between younger and older adults for intact and reversed pairs, we did expect poorer recognition performance for recombined and recombined and reversed pairs in older relative to younger adults. The second experiment followed the same logic as Experiment 1, but increased the demands on flexible retrieval by asking participants to respond "Old" only to intact pairs. We hypothesized that increasing the demands on flexible retrieval would increase the chances of finding an age-related difference in recognition performance for reversed, recombined and recombined and reversed pairs, although not for pairs with low retrieval demands (i.e., intact pairs).

Experiment 1

In Experiment 1, participants studied unrelated word pairs (e.g., A–B, C–D), and were later tested with intact (A–B), reversed (B–A), or recombined (A–D, referred to as Recombined 1–2 pairs, or B–C, referred to as Recombined 2–1 pairs, with 1 and 2 referring to the position of the word in the original word pairing). At test, participants were instructed to respond "Old" to pairs that were intact *or* reversed, and to say "New" to any type of recombined pairs (see Table 1 for word pair types and correct responses). This procedure generally followed Giovanello et al. (2009), but was adapted slightly for older adults (through the use of longer presentation times for both age groups). In addition, recombined pairs that differed in positional information (the Recombined 2–1 pairs) were included in the present design.

Table 1. A summary of the word pair types and correct responses in Experiment 1 and Experiment 2. For the examples below, assume A—B and C—D are studied word pairs (each letter represents a single word), and that none of the words appeared in more than one pair in the actual experiments. For the Recombined pairs, 1 and 2 refer to the position of the word in the original word pairing (1 = 1st position, 2 = 2nd position within the original pair), such that 1–2 keeps the original position of the words within the recombined pair constant, whereas the 2–1 recombination involves new positions of the words within the pair.

Word Pair Type	Example	Experiment 1 Correct Response	Experiment 2 Correct Response
Intact	A–B	"Old"	"Old"
Reversed	D–C	"Old"	"New"
Recombined 1–2	A–D	"New"	"New"
Recombined 2–1	B–C	"New"	"New"

Method

Participants

Thirty younger adults (YA; M_{age} = 20.3 years; *SD* = 1.5 years; 18 females) and thirty older adults (OA; M_{age} = 73.1 years; *SD* = 7.3 years; 20 females) participated in the experiment. Younger adults were recruited from the University of North Carolina at Chapel Hill and Duke University and participated for course credit or monetary compensation. Older adults were recruited from Chapel Hill and surrounding community and paid for their participation. All participants were right-handed, fluent English speakers with normal or corrected-to-normal vision. All participants were screened to ensure that they were healthy, reported no history of psychiatric (including depression) or neurological disorders. Informed consent was obtained from all participants according to the institutional review boards at the University of North Carolina at Chapel Hill and Duke University. In addition, older adult participants were given a battery of neuropsychological tests to assess their mental functioning. The neuropsychological battery consisted of the Mini-Mental State Exam, subtests from the Wechsler Adult Intelligence Scale (WAIS)—Revised (Mental Arithmetic and Mental Control) and WAIS-III (Digit Span Backward), subtests from the Wechsler Memory Scale—Revised (Logical Memory I and Verbal Paired Associates), the California Verbal Learning Test, the Wisconsin Card Sorting Test, and the Controlled Oral Word Association Test. The neuropsychological data, collected from each older adult participant within six months of their participation in this study, are presented in Table 2.

Stimuli and procedures

Stimuli were 96 one- to three-syllable unrelated nouns with a frequency range of 1–200 (Mean Frequency = 46.7; *SD* = 47.6; Francis & Kučera, 1982), and these words were randomly paired by the experimenter to create 48 unrelated word pairs. Following a short practice session for task familiarization, participants saw one unrelated word pair (e.g., A–B, C–D) every 6 s for a total of 48 trials and were told to remember the word pairs for an upcoming memory test. Immediately following the encoding phase, participants were shown one unrelated word pair every 8 s and instructed to decide whether or not the words had been shown together previously, and in addition, to make a confidence judgment about their decision on a scale of 1–10.[1] Participants were informed that the words in a pair would sometimes appear in the reverse order or would be re-paired with other words. Each word appeared only once during the

Table 2. Demographic and neuropsychological information for older adult participants in Experiment 1 and Experiment 2.

	Experiment 1	Experiment 2
Sample size (*N*)	30	30
Education (*SD*), years	17.4 (2.3)	18.3 (2.2)
MMSE	29.1 (1.1)	29.1 (1.4)
Mental Arithmetic (WAIS-R)	16.3 (2.9)	16.1 (3.3)
Mental Control (WAIS-R)	27.0 (3.2)	26.4 (5.5)
Digit Span Backward (WAIS-III)	7.9 (2.4)	8.0 (3.6)
Logical Memory Immediate (WMS-R)	29.4 (4.7)	27.5 (6.9)
Verbal Paired Associates Immediate (WMS-R)	22.6 (7.2)	23.7 (7.0)
Verbal Pairs Associates Delay (WMS-R)	6.8 (1.7)	6.1 (1.9)
California Verbal Learning Task *	13.3 (2.1)	11.8 (3.3)
Wisconsin Card Sorting Task *	4.1 (1.8)	5.5 (1.1)
COWAT	49.0 (13.3)	47.5 (17.2)

WAIS-R, Wechsler Adult Intelligence Scale—Revised; WMS-R, Wechsler Memory Scale—Revised; WAIS-III, Wechsler Adult Intelligence Scale—Third Edition; COWAT, Controlled Oral Word Association Test. *Due to time constraints, these tests were only applied to 20 participants in Experiment 1, and 20 participants in Experiment 2.

memory test. Equal numbers (i.e., 12) of the four different types of word pairs were presented on the recognition test: Intact Pairs (pairs of words previously seen together; A–B), Reversed Pairs (pairs of words previously seen together but in the reversed order; D–C), Recombined 1–2 Pairs (pairs of words previously seen, but not together; A–C), and Recombined 2–1 Pairs (pairs of words previously seen, but not together and in the reversed order; B–D). The word pairs were counterbalanced across the four experimental conditions (all different word pair types and correct responses are summarized in Table 1).

Results

Figure 1 shows the proportion of correct responses for each memory task for each age group (data available at https://osf.io/657hm/). Endorsing as "Old" Intact Pairs and Reversed pairs, and endorsing as "New" Recombined 1–2 or Recombined 2–1 pairs, were considered hits (Table 1). A generalized linear mixed-effects regression model (link = "logit") was computed in which age group (YA, OA) and word pair type (Intact Pair, Reversed Pair, Recombined 1–2, Recombined 2–1) were fixed factors, and recognition accuracy (incorrect coded as 0, correct coded as 1) was the outcome variable. The participant and the particular word pair (i.e., the two words presented at each trial) served as crossed random effects (random intercepts only) in the model. The reference level for the age group factor was YA, and the reference level for word pair type factor was Intact Pair. Data were analyzed using R (R Development Core Team, 2014) with the lme4 software package (Bates, Maechler, Bolker, & Walker, 2015; for the advantages of using linear mixed-effects regression models for accuracy measures, see Dixon, 2008). As hypothesized, there was a significant interaction effect between age group and word pair type for Recombined 2–1 ($b = -.74$, $SE = .32$, $Z = -2.34$, $p = .019$, 95% CI [−1.36, −.12]), although not for Recombined 1–2 (Full results are depicted in Table 3).

Two subsequent separate generalized linear mixed effects models were computed, in which participant and the particular word pair served as crossed random effects (random intercepts only), age served as the only fixed effect, and recognition accuracy (incorrect coded as 0, correct coded as 1) was the outcome variable. 95% CIs were computed for

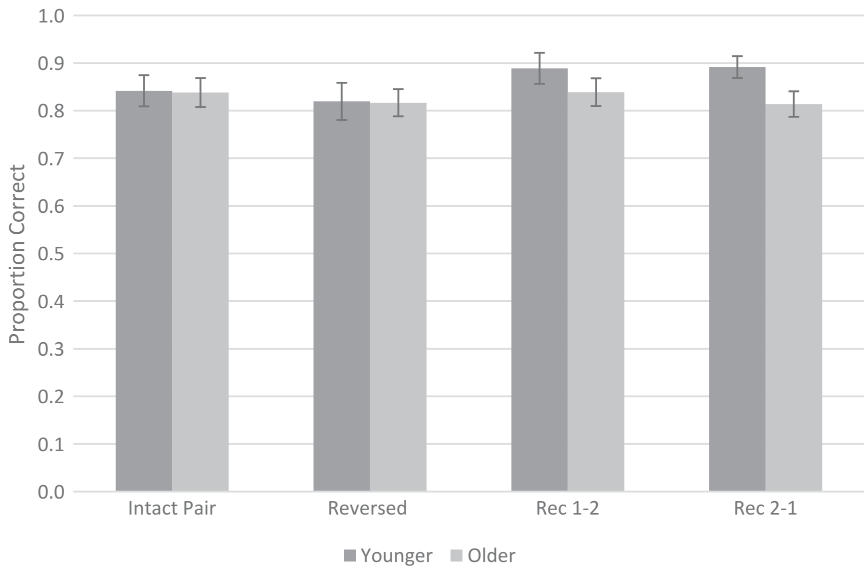

Figure 1. Proportion of correct responses as function of the different word pair types presented at test for younger and older adults in Experiment 1. Responding "Old" to Intact Pairs and the Reversed Pairs, and "New" to Recombined 1–2, and Recombined 2–1, are considered Hits. Error bars represent standard errors of the mean.

Table 3. Full results of a generalized linear mixed-effects regression model with data from Experiment 1, with age group and word pair type as predictors of recognition accuracy.

	b	*SE*	*Z*	*p*	95% CI
Word Pair Type [T. Reversed]	−.21	.22	−.95	.34	[−.65, .22]
Word Pair Type [T. Recombined 1–2]	.48	.24	1.99	.047	[.01, .95]
Word Pair Type [T. Recombined 2–1]	.51	.24	2.10	.036	[.03, .99]
Age [T. OA]	−.13	.36	−.37	.71	[−.83, .57]
Word Pair Type [Reversed] x Age [T. OA]	−.02	.30	−.07	.95	[−.61, .56]
Word Pair Type [Recombined 1–2] x Age [T. OA]	−.52	.32	−1.63	.10	[−1.14, .10]
Word Pair Type [Recombined 2–1] x Age [T. OA]	−.74	.32	−2.34	.019	[−1.36, −.12]

N = 60. All 95% CIs are for the beta-estimates. "T" indicates "True," as per R output.

beta-estimates. These models revealed no significant difference in recognition accuracy between younger and older adults on Intact Pairs ($b = .00$, $SE = .40$, $Z = .00$, $p = .99$, 95% CI [−.78,.78]), and a significant difference between younger and older adults on Recombined 2–1 pairs ($b = -.70$, $SE = .33$, $Z = -2.13$, $p = .034$, 95% CI [−1.35, −.05]). These results suggest that while older and younger adults show comparable levels of recognition performance in Intact, Reversed, and Recombined 1–2 word pairs, older adults have poorer recognition performance relative to younger adults in the condition for which the greatest amount of flexible retrieval is demanded (i.e., Recombined 2–1).

Experiment 2

We conducted a second experiment, not only to confirm the age-related difference in recognition for Recombined 2–1 pairs found in Experiment 1, but also to examine differences in recognition between YA and OA when the task requires rejection of the Reversed pairs (B–A). In Experiment 1, YA and OA may have benefited from answering "Old" to both intact *and* reversed pairs. In Experiment 2, we make recognition a bit more demanding by instructing participants to reject reversed pairs and classify them as "New". This modification would allow us to examine whether or not the age-related differences in recognition go beyond the Recombined 2–1 pairs found in Experiment 1 when retrieval demands for reversed pairs increases.

Method

Participants

Thirty younger adults (YA; Mean age = 19.4 years; *SD* = 1.1 years; 17 female) and thirty older adults (OA; Mean age = 74.4; *SD* = 8.0; 20 female) participated in the experiment. None of the individuals had participated in Experiment 1. As in Experiment 1, younger adults were recruited from the University of North Carolina at Chapel Hill and Duke University and participated for course credit or monetary compensation. Older adults were recruited from the Chapel Hill and surrounding community and paid for their participation. All participants were right-handed, fluent English speakers with normal or corrected-to-normal vision. All participants were screened to ensure that they were healthy, reported no history of psychiatric (including depression) or neurological disorders. Informed consent was obtained from all participants according to the institutional review board at the University of North Carolina at Chapel Hill and Duke University.

Additionally, older adult participants were given a battery of neuropsychological tests to assess their mental functioning. The neuropsychological battery consisted of the Mini-Mental State Exam, subtests from the Wechsler Adult Intelligence Scale (WAIS)-Revised (Mental Arithmetic and Mental Control) and WAIS-III (Digit Span Backward), subtests from the Wechsler Memory Scale—Revised (Logical Memory I and Verbal Paired Associates), the California Verbal Learning Test, the Wisconsin Card Sorting Test, and the Controlled Oral Word Association Test. The neuropsychological data, collected from each older adult participant within six months of their participation in this study, are presented in Table 2.

Stimuli and procedures

The stimuli and procedures for Experiment 2 were identical to Experiment 1 with one critical exception. At test, participants were instructed to decide whether or not the words had been shown together previously *in the exact order*. Participants were given clear instructions, and examples, about how they should respond "Old" only to word pairs that were presented earlier, in the same order, and they should respond "New" to word pairs that were rearranged in any way (including Reversed and Recombined pairs).

Results

Figure 2 shows the proportion of correct responses for each memory task for each age group (data available at https://osf.io/657hm/). Importantly, in Experiment 2, endorsing only Intact Pairs as "Old", while endorsing as "New" all other word pair types (i.e., Reversed Pairs, Recombined 1–2, or Recombined 2–1), were considered hits (Table 1).

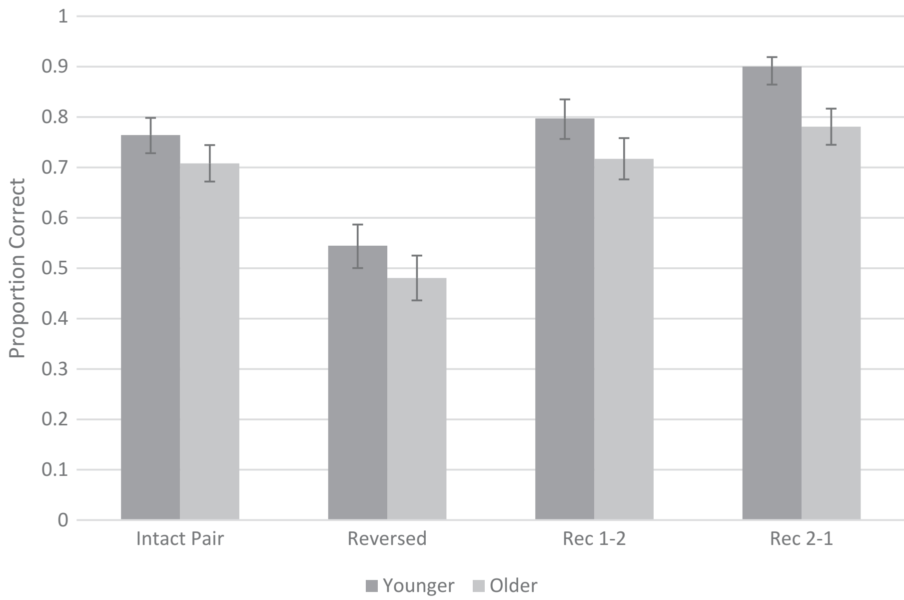

Figure 2. Proportion of correct responses as function of the different word pair types presented at test for younger and older adults in Experiment 2. Responding "Old" to Intact Pairs, and "New" to Reversed, Recombined 1–2, and Recombined 2–1 pairs, are considered Hits. Error bars represent standard errors of the mean.

A generalized linear mixed-effects regression model (link = "logit") was computed in which age group (YA, OA) and word pair type (Intact Pair, Reversed Pair, Recombined 1–2, Recombined 2–1) were fixed factors, and recognition accuracy (incorrect coded as 0, correct coded as 1) was the outcome variable. The participant and the particular word pair served as crossed random effects (random intercepts only) in the model. The reference level for the age group factor was YA, and the reference level for word pair type factor was Intact Pair. As predicted, there was a significant interaction effect between age group and word pair type for Recombined 2–1 (b = −.62, SE = .29, Z = −2.18, p = .029, 95% CI [−1.18, −.06]), although not for Recombined 1–2 or Reversed Pair (see Table 4 for full results).

As in Experiment 1, two separate subsequent generalized linear mixed effects models were computed, with participant and the word pair trial as crossed random effects (random intercepts only), age as fixed factor, and recognition accuracy (incorrect coded as 0, correct coded as 1) as outcome variable. 95% CIs were computed for beta-estimates. These models revealed that while there was no significant difference in recognition accuracy between younger and older adults on Intact Pairs (b = −.34, SE = .29 Z = −1.20, p = .23, 95% CI [−.90, .22]), there was a significant difference between young and older adults on Recombined 2–1 pairs (b = −.99, SE = .33, Z = −3.02, p = .003, 95% CI [−1.63, −.35]). These results corroborate the findings from Experiment 1, whereby relative to younger adults, older adults show comparable levels of recognition performance in Intact, Reversed, and Recombined 1–2 word pairs, but poorer recognition performance in the condition for which the greatest amount of flexible retrieval is demanded (i.e., Recombined 2–1).

Table 4. Full results of a generalized linear mixed-effects regression model with data from Experiment 2, with age group and word pair type as predictors of recognition accuracy.

	b	*SE*	*Z*	*p*	95% CI
Word Pair Type [T. Reversed]	−1.04	.18	−5.92	< .001	[−1.38, −.70]
Word Pair Type [T. Recombined 1–2]	.19	.19	1.03	.30	[−.18, .57]
Word Pair Type [T. Recombined 2–1]	1.19	.23	5.23	< .001	[.74, 1.63]
Age [T. OA]	−.32	.22	−1.47	.14	[−.74, .11]
Word Pair Type [Reversed] x Age [T. OA]	.11	.23	.46	.65	[−.35, .56]
Word Pair Type [Recombined 1–2] x Age [T. OA]	.00	.25	−.02	.99	[−.50, .49]
Word Pair Type [Recombined 2–1] x Age [T. OA]	−.62	.29	−2.18	.029	[−1.18, −.06]

N = 60. All 95% CIs are for the beta-estimates. "T" indicates "True," as per R output.

General discussion

The current experiments sought to investigate differences in recognition of associative information during flexible retrieval in younger and older adults. In Experiment 1, flexible retrieval was relatively undemanding, and we expected that recognition performance in older adults would be equivalent to that of younger adults for intact and reversed pairs, while it would be worse for recombined pairs, and even worse for recombined and reversed pairs, as these involved the most demanding conditions of flexible retrieval. The results of Experiment 1 only lend partial support to our hypothesis, as older adults did show reduced recognition performance for recombined and reversed word pairs relative to younger adults. However, no differences were found for recombined pairs. In Experiment 2, we increased the flexible retrieval demands and expected that with this increase associative memory recognition would be worse in older relative to younger adults for the most demanding trials (i.e., recombined and recombined and reversed). Our results corroborated the findings of Experiment 1, and once again lend partial support to our hypothesis, as recognition performance was worse for older relative to younger adults in recombined and reversed, but not in recombined or reverse pairs.

Previous results on associative memory have shown that, when flexible retrieval demands are not too high, recognition performance in older adults does not differ from younger adults (Giovanello & Schacter, 2012). In the current experiments, however, we gradually increased flexible retrieval demands and showed that, under more demanding circumstances, recognition for associative information is reduced in older relative to younger adults. These findings suggest that both younger and older adults can engage in flexible retrieval, although older adults show associative memory deficits in recognition when flexible retrieval demands require remembering both the precise position and order of information.

One mechanism that may guide flexible remembering is familiarity, as previous research has shown only small age-related declines in the use of familiarity, but much more pronounced age-related deficits in detailed recollection (Jacoby & Rhodes, 2006). In this study, older adults were able to successfully recognize intact, reversed, and recombined pairs, suggesting that in these cases, they may use a familiarity-based form of conceptual processing that allows for access to order information. However, consistent with the associative deficit hypothesis (Naveh-Benjamin, 2000), older adults showed poorer recognition performance for the recombined and reversed pairs, when positional information maximally differed from study to test. That is, older adults were not able to use positional and serial information when they maximally differ, in order to correctly reject recombined and reversed pairs at the same level as younger adults. This finding may reflect a deficit in more precise representations of position and serial information and is consistent with other work that shows specific deficits in positional and sequential information in older adults (e.g., Chalfonte & Johnson, 1996).

In terms of the use of familiarity and recollection in the present task, older adults could have use familiarity to endorse reverse pairs (in Experiment 1), as well as to reject them when instructions warrant this (in Experiment 2). In the present experiments, there may be two uses of familiarity: (1) familiarity for the items; (2) familiarity for the associations. It is possible that both age groups have formed a global familiarity for the directional associative link between the two items in the word pair at encoding, and this leads older adults to perform well for the reversed word pair condition (Overman, McCormick-Huhn, Dennis, Salerno, & Giglio, 2018). Although the task requirements change in Experiment 2, older adults may still use familiarity regarding the association of reversed pairs to reject them, and this suggests that this global or gist-based familiarity is available (and helpful) for older adults. However, for the recombined pairs, participants may not have been able to rely solely on familiarity in terms of the directionality of the link—they must use recollection to reject pairs that are recombined—and here older adults' performance is worse than younger adults' (especially for the recombined and reverse pairs, when information about both spatial and sequential associations is critical). This interpretation suggests that associative recollection is somewhat impaired for older adults (e.g., Jacoby & Rhodes, 2006; Rhodes, Castel, & Jacoby, 2008; Yonelinas, 2002), and that older adults have more difficulty employing a recall-to-reject strategy when making decisions regarding recombined and reversed pairs (see also Cohn et al., 2008).

In addition, findings from this study support other work that has shown age-related differences in the ability to successfully use context to overcome the adverse effects of misleading cues and also to take advantage of the benefits of facilitative cues to enhance memory performance (e.g., Benjamin, 2011; Naveh-Benjamin & Craik, 1995). In a related field, other research has shown that older adults do not effectively use background music to help identify target voice information, when the background music can facilitate performance due to the contextual match between the study and test episodes (Russo & Pichora-Fuller, 2008). Specifically, younger listeners attempted to "tune in" the background music to help them later at test, but older listeners attempted to "tune out" the background, and thus do not show later benefits when there is a match between study and test background music. This is somewhat similar to the Recombined 1–2 vs 2–1 pairs in the present task, as older adults did not show a benefit of using the incongruent positional information in rejecting the Recombined 2–1 pairs. It remains unclear if older adults encode this positional information, but do not use it successfully (e.g., Koutstaal, 2003), or if older adults rely more on conceptual encoding that allows for flexible retrieval of the words, but not any benefits when the more precise positional information can enhance the ability to reject lure pairs. Moreover, a limitation of the current experiments is that the extent to which possible pre-experimental associations between otherwise unrelated words cannot be fully ruled out (Amer, Giovanello, Grady, & Hasher, 2018; Delhaye & Bastin, 2016). Further studies are needed to clarify the role of individual differences in recognition performance in younger and older adults.

A useful framework for considering the present findings is Johnson's MEM model (Johnson, 1994; Johnson, Hashtroudi, & Lindsay, 1993). Here, both the perceptual and reflectory memory systems contain processes that allow for the construction of associations between items, but these processes have distinct characteristics. At a perceptual level, individual words are encoded in terms of their spatial relation to each other, such that a new unit is formed that represents the spatial/temporal-order relationship between the two words. At a conceptual level, the process of forming of a new associative link between the two words allows for the comparison and evaluation of these two words as a pair in a different context. The present findings suggest that older adults have difficulty with the more perceptual fusion of positional information, but can access the more conceptually mediated information that then allows for flexible retrieval. An avenue for future research would be to further examine memory for the different components involved in successful retrieval of associative information, as these may be differentially affected in cognitive aging.

Note

1. Initially, we sought to explore the relationship between confidence and accuracy. However, the confidence data was non-normally distributed, and its inclusion would have complicated the statistical models unnecessarily. As such, confidence data are not reported in the current manuscript.

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No potential conflict of interest was reported by the authors.

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