A prelearning manipulation falsifies a pure associational deficit account of retrieval shift during skill acquisition.

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Hines, J. Hertzog, C. & Touron, D. R. (2012). A prelearning manipulation falsifies a pure associational deficit account of retrieval shift during skill acquisition. *Aging Neuropsychology and Cognition, 19(4),* 449-478.

Abstract:

Older adults adopt memory-based response strategies during consistent practice more slowly and less completely than younger adults. In two experiments, participants either prelearned all, half, or none of the noun-pair stimuli prior to the completion of a standard noun-pair lookup task. Higher proportions of prelearning generally led to a faster and more complete strategic shift from visual scanning to memory retrieval during the lookup task, and a strong prelearning criterion for all items eliminated the age-related slowing of retrieval shift. However, the 50% prelearned condition resulted in strategy shift that was inconsistent with simple mechanistic associative learning, revealing a strategic set that was retrieval-avoidant in older adults.

Keywords: skill acquisition, aging, strategy use, associative learning | neuropsychology | memory

Article:

Skill acquisition is characterized by a shift from more effortful cognitive processing to more automatic processing that is not dependent on allocation of central executive resources and cognitive control (e.g., Ackerman, 1987; Shiffrin & Schneider, 1977). In some skill acquisition tasks, the development of automaticity involves a shift from a computational strategy to a memory retrieval strategy. This shift typically replaces slow implementation of an algorithm, as in a mental arithmetic task, to direct retrieval of the correct answer, bypassing the requirement to compute a solution.

Strategic shifts toward more automatized processing have been hypothesized to result deterministically from repeated exposures to to-be-learned stimuli-response pairings. For example, Logan (1988) argued that memory-based responding is a direct outcome of practice making memory retrieval faster than completion of the algorithm. Upon viewing a stimulus, both types of processing essentially operate in parallel, with an individual's response resulting from the faster process (i.e., the first to reach an accuracy criterion is selected). As levels of stimulus exposure increase, so does the speed of automatic, memory-based processing, and the rate of strategic shift is a consequence of improved retrieval efficiency (Palmieri, 1999). Other skill acquisition models allow for strategic choice, but model this choice as a direct outcome of improved memory strength due to repeated stimulus exposures (e.g., Bajic & Rickard, 2009; Rickard, 1997).

Other theorists argue that, in addition to influences of associative memory strength, the algorithm-to-retrieval shift in skill acquisition is also influenced by top-down strategic choice mechanisms. For instance, Haider, Frensch, and Joran (2005) explicitly argued for a volitional component to strategic choice in such tasks (see also Gray & Fu, 2004). In the Haider et al. (2005) study, individuals showed declarative knowledge of the memory-based strategy, generalized it to a dissimilar task context, and did not adopt it when evidence was available that the strategy could not be applied to all instances in a problem set. Moreover, the algorithm to retrieval shift does not typify all task contexts. In general, individuals may opt to select strategies that minimize costs and effort based on task affordances (Bourne, Healy, Kole, & Graham, 2006; Touron & Hertzog, 2004b). Bourne, Raymond, and Healy (2010) showed that prelearning a rule relevant to their binary classification task affected strategic shift in a manner consistent with volitional choice. In some instances, reliance on rule-based processing persisted after rule prelearning, suggesting that the use of rule-based processing was reinforced by prior exposure. Moreover, there were consistent individual differences in whether people shifted to a memory-based strategy, consistent with top-down influences on strategic choice (see also Haider et al., 2005; Rogers, Hertzog, & Fisk, 2000).

This paper concerns the issue of age differences in strategic shift in a simple skill acquisition task, and whether observed age differences are a function of slowed associative learning. Older adults are capable of developing automatic memory search after extended practice, showing that they are capable of forming unitized representations in long-term memory, although the rate of acquiring this automaticity is slowed by aging (e.g., Hertzog, Cooper, & Fisk, 1996). Likewise, associative learning tasks often reveal age differences in the rates at which younger and older adults learn new associations (e.g., Bender, Naveh-Benjamin, & Raz, 2010; Kausler, 1994). Strategic choice also contributes to older adults' slower learning rates on several types of cognitive tasks (Lemaire, 2010; Kausler, 1994; Rogers et al., 2000).

Under intentional learning conditions, some age-related variance in learning is due to differences in the spontaneous use of effective strategies between younger and older adults. For example, it appears that older adults are less likely to engage in spontaneous use of mediators for associative learning (e.g., Dunlosky & Hertzog, 2001; Hertzog & Dunlosky, 2004; Kausler, 1994). However, training people to use encoding strategies does not ameliorate older adults' associative memory deficits (e.g., Shing, Werkle-Bergner, Li, & Lindenberger, 2008; but see Naveh-Benjamin, Brav, & Levy, 2007). Older adults also demonstrate reduced access to self-generated mediators at test (Dunlosky, Hertzog, & Powell-Moman, 2005). It appears that older adults experience deficits in associative binding (e.g., Chalfonte & Johnson, 1996; Shing et al., 2008) and retrieval access (e.g., Cohn, Moscovitch, & Emrich, 2008) that should slow rates of incidental associative learning during skill acquisition. 1

The current experiments examined age differences in the shift to a memory-retrieval based strategy in the Noun Pair Lookup Task (NPLT; Ackerman & Woltz, 1994). This task combines a visual search task with an associative learning affordance. Participants are shown a series of target noun pairs (NPs) in the middle of a computer screen along with a table containing multiple NPs at the top of the screen; the goal during each trial is to verify whether the target pair matches one of the pairings in the table. In consistently mapped versions of the task, the pairings in the table remain the same across trials, and individuals who have learned the target association for a given pair can make the judgment based on associative recognition memory (i.e., a memory-retrieval strategy) rather than using visual scanning (i.e., verifying the target pairing by looking at the table above). Eye movement research confirms that participant reports of using memory retrieval in the NPLT are accompanied by a reduction in information-seeking gazes to the lookup table (Touron, Hertzog, & Frank, 2011). The shift to a memory-retrieval strategy substantially reduces NPLT response times (RTs), but at the cost of risking errors early in practice due to inaccurate associative recognition responses.

The associative learning deficit (ALD) hypothesis states that slower rates of RT improvement during skill acquisition by older adults are completely determined by slower rates of learning the new associations (Cerella, Onyper, & Hoyer, 2006; Onyper, Hoyer, & Cerella, 2006, 2008). In contrast, the retrieval avoidance (RA) hypothesis states that older adults are more likely to avoid basing NPLT responses on memory retrieval, even when they have actually learned the new associations to a degree that would enable accurate responding. The RA hypothesis does not deny the existence of an ALD, it merely argues that factors other than ALD, such as negative memory beliefs on the part of older adults, contribute to the age differences in rates of retrieval shift (Touron & Hertzog, 2004a). There is evidence suggesting influences on NPLT retrieval shift other than learning the associations, thereby casting doubt on the sufficiency of the ALD account of age differences in NPLT retrieval shift (e.g., Rogers et al., 2000; Rogers & Gilbert, 1997 Touron & Hertzog, 2004a, 2004b). For example, monetary incentives to respond quickly increase older adults' use of the retrieval strategy and hasten their retrieval shift (Touron & Hertzog, 2009; Touron, Swaim, & Hertzog, 2007).

Touron and Hertzog (2004a) used interpolated memory probes during the NPLT to show that older adults' memory retrieval strategy use lagged considerably behind their improvements in recognition memory performance. In one experiment, young and older adults experienced a prelearning manipulation, memorizing the NPs prior to starting practice on the NPLT. Despite having substantial knowledge of the pairings before task onset, older adults still demonstrated a substantial delay before shifting toward a retrieval-based strategy, supporting the RA hypothesis over the ALD hypothesis.

Cerella et al. (2006) and Onyper et al. (2006, 2008) have argued for the sufficiency of the ALD hypothesis and against the evidence that the delayed shift is influenced by other factors. In particular, Cerella et al. (2006) argued that Touron and Hertzog's (2004b) evidence for an RA effect might be determined by an ALD alone. They pointed out that one manifestation of ALD should be variable and slowed retrieval RTs for older adults. An older individual could successfully retrieve answers in recognition memory tests, but with insufficient fluency to promote retrieval use in the NPLT. This argument would apply irrespective of whether one views retrieval as an outcome of a race model (e.g., Logan, 1988) or a rapid initial strategy selection (e.g., Bajic & Rickard, 2009). In either case, slowed rates of retrieval on NPLT trials should produce a greater proportion of trials with visual scanning.

Recent research has found larger age differences in associative recognition memory test performance when the stimuli are rearranged or mismatched pairs (Cohn et al., 2008; Hines, Touron, & Hertzog, 2009); moreover, much of the age-related associative deficit identified by Naveh-Benjamin and co-workers (e.g., Naveh-Benjamin, 2000) is attributable to poor performance on rearranged trials (Bender et al., 2010; Cohn et al., 2008). The earlier work by Touron and Hertzog (2004a, 2004b) pooled intact and rearranged items when examining rates of memory adoption. Hertzog and Touron (2011) evaluated intact and rearranged items separately in the NPLT, finding reliable interactions of intact versus rearranged pairs with age in both the accuracy and the subjective confidence of recognition memory tests. Older adults performed more poorly on recognition test probes for rearranged pairs, and this deficit was maintained throughout practice in the NPLT. Moreover, older adults reported lower confidence in their memory responses for rearranged items, which was associated with less frequent use of the memory retrieval strategy. Such findings are consistent with the Cerella et al. (2006) argument that older adults' recognition test accuracy, in the aggregate, may not necessarily indicate sufficient underlying levels of learning to afford accurate retrieval use in the NPLT. This evidence and Cerella et al.'s (2006) argument warranted a re-evaluation of the prelearning manipulation and its consequences.

We hypothesized that older adults' retrieval shift in the NPLT would be governed by (1) age-related declines in associative memory and (2) a conservative strategic choice to avoid retrieval-based responding. In two experiments, a more stringent prelearning criterion than that used by Touron and Hertzog (2004b) led to more fluent NP retrieval, especially for older adults. This level of learning of the NP associations could eliminate age differences in the NPLT retrieval shift entirely, according to the ALD hypothesis. To foreshadow our results, Experiment 1 supported this conjecture – unlike Touron and Hertzog's (2004b) results, older adults shifted from scanning to retrieval as quickly as younger adults with more extensive prelearning of NP items. Experiment 2 then demonstrated the existence of a strategic set or context effect, whereby mixing 50% prelearned and 50% new items in the NPLT produced delayed retrieval shifts for older adults that were qualitatively divergent from a 100% prelearned condition, consistent with the RA hypothesis.

EXPERIMENT 1

Experiment 1 used a variation of the NPLT in which younger and older adults prelearned either 0 or 100% of the NP stimuli prior to beginning the actual NPLT. Touron and Hertzog (2004b) required participants to meet a prelearning criterion of 90% (9/10 or 18/20) correct responses on one recognition test block. In the current study, all participants who prelearned NPs were required to meet the stricter criterion of 96% (23/24) correct responses on two consecutive test blocks. Both the smaller number of NPs used in the current experiments and the more stringent prelearning criterion could have contributed to a higher degree of NP acquisition during prelearning, either by reducing potential interference effects or by requiring a higher degree of memory competence to meet the prelearning criterion. As shown later, NPLT performance manifested stronger NP learning for prelearned items, as evidenced by both RTs and retrieval adoption.

Our main question of interest was whether we could eliminate the age differences in retrieval shift. By itself, eliminating the age differences by prelearning the associations would not fully test the ALD hypothesis. It is likely that if the stimuli were well-known, highly learned associations (such as the first and last names of one's 12 closest friends and relatives), both young and old adults would rely exclusively on memory retrieval after the first block of trials because no further associative learning was required. Showing that people will rely on retrieval for highly overlearned items is not sufficient evidence against RA as it operates in the standard NPLT. However, finding prelearning conditions that eliminate age differences in rates of retrieval shift sets the stage for evaluating ALD with other experimental manipulations (e.g., Bourne et al., 2010).

Previous work in our laboratories also indicated that age differences in accuracy of response time monitoring might influence the retrieval shift (Hertzog, Touron, & Hines, 2007). Hence we also manipulated whether participants were asked to estimate how long it had taken to make an NPLT response. This variable did not affect the phenomena we report here, so it is not discussed further.

Method

Design

The experiment was a 2 (Age: Young, Old) × 2 (Noun Pair Exposure: 0% Prelearning, 100% Prelearning) × 2 (Response Time Estimation: Performed, Not Performed) between-subjects design, with age and NP exposure as between-subjects independent variables and response time estimation as a within-subjects variable.

Participants

The sample consisted of 39 younger adults between the ages of 18 and 25 years (see Table 1 for participant characteristics). These younger adults were students of the Georgia Institute of Technology and were given course credit for their participation. Forty-three adults ranging in age from 60 to 75 years were recruited from the community surrounding Georgia Tech, receiving an honorarium of $40 for their participation. All participants were pre-screened for basic health issues that could impede participation (e.g., poor vision or diagnosed memory disease). No participants were removed from our analyses as a result of these exclusions.

Table 1. Participant characteristics for Experiments 1 and 2

	Experiment 1*		Experiment 2*	
Measure	Young	Old	Young	Old
Age	19.6 (0.8)	70.9 (0.7)	21.4 (0.6)	69.5 (0.6)
Vocabulary	32.6 (0.6)	33.9 (0.5)	28.7 (0.5)	34.3 (0.5)
Wechsler Speed	71.5 (2.4)	49.9 (2.0)	67.1 (1.6)	50.9 (1.6)
Wechsler Recall	7.8 (0.3)	4.8 (0.3)	7.6 (0.3)	5.2 (0.3)

Note: Age refers to chronological age in years. Vocabulary refers to the number correct out of 40 in the Shipley vocabulary test. Wechsler Speed refers to the number of items filled in correctly on the first section of the Wechsler Adult Intelligence Scale – Revised Digit Symbol Subtest. Wechsler Recall refers to the second section of the Wechsler subtest requiring participants to recall as many of the 9 test symbols as possible.

*Age main effects reliable at $p < .005$. No reliable statistical differences existed between any prelearning conditions or in the form of Age × Prelearning Condition interactions.

Materials and Procedure

Participants first completed a brief personal data questionnaire, the Shipley Institute of Living vocabulary test (Zachary, 1986), and the Digit Symbol subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1981). Typical age effects were found (see Table 1).

The associative recognition task was programmed in Visual Basic 6.0. Stimuli were presented using a 15-point Arial font on a 15-inch LCD monitor with a resolution of 1024 × 768. Participants were seated at a height and distance that optimized their screen viewing and comfort. Self-paced instructions preceded each portion of the task.

The NPLT consisted of 30 blocks of 24 NP recognition trials. During each trial, a lookup table was presented at the top of the computer screen that contained 12 NPs in a 4 × 3 grid. The placement of each pair in the table was randomized between trials (as was the order of target pairs presented in each block), but the pairings remained unchanged across practice. A target pair was presented in the center of the screen on each trial; half of the 24 target pairs matched one presented in the table (i.e., intact pairings), and half were rearranged (i.e., the first word from a pair was coupled with a second word from a different pair, sampled without replacement). Individual nouns were presented in capital letters and always retained their position on the left or right side of a pairing.

Each trial was preceded by a 500-ms centrally located fixation cross (‘+’) followed by the simultaneous presentation of the target pair and lookup table. Participants pressed keys marked Y or N to indicate whether the target pair matched one of the pairs in the table. After the recognition response was made, another screen was presented to ask participants ‘how did you get your answer?’ The following options were given: ‘S’ (to indicate they scanned the table), ‘M’ (to indicate they used their memory of the pairings), ‘B’ (i.e., ‘Both’; e.g., they remembered a correct pairing and then scanned the table to verify the response), or ‘O’ (i.e., ‘Other’; e.g., they mis-keyed or forgot the strategy they used). Participants pressed keys labeled to correspond to these strategy options. Strategy reports were followed by RT estimates. Participants were offered a short self-paced break prior to the beginning of the next study-test block. A mandatory break of 1 minute was given after the 10th and 20th test blocks.

Participants were assigned at random to receive or to not receive noun pair prelearning. Those in the 0% prelearning condition began the NPLT directly after completing the pretests, while those in the 100% prelearning condition completed a separate associative recognition task prior to beginning the NPLT. Participants prelearned to criterion the 12 NPs used in the subsequent NPLT. Each block of prelearning consisted of a sub-block of participant-paced item-level study followed by a sub-block of item-level recognition testing. Each study trial began with a 500-ms fixation cross followed by the noun pair to be studied until the participant pressed the spacebar. A blank screen was then presented for 250 ms. Another study trial followed until all 12 items had been studied. During each recognition test block, all 12 NPs were shown in both an intact and rearranged configuration. After each recognition test trial, participants provided a confidence judgment (CJ) rating their confidence in the accuracy of the previous recognition trial on a continuous scale from 0 to 100% by entering any value within in that range in a text box. Noun pair presentation orders were randomized independently for both study and test prior to each block of prelearning.

Participants transitioned from the prelearning task to the NPLT by meeting one of two criteria: they could either attain a level of recognition performance greater than or equal to 23 of 24 correct recognition responses in two successive test blocks or complete 10 study-test blocks (the number of opportunities participants had to meet the memory criterion). Four older adult participants who did not meet the prelearning criterion by block 10 of the associative recognition task were not included in our analyses.

Results

SAS Proc Mixed was used to analyze all data and produce relevant marginal means and standard errors (Littell, Milliken, Stroup, Wolfinger, & Schabenberger, 2006). Analyses related to memory use utilized all response data, while RT analyses were performed on correct responses only. In the following analyses, the variable Match indicates whether or not test pairs were presented in an intact or rearranged form on a given trial, and the variable Block represents the temporal aspect of the testing environment. Both Match and Block were always included as class-level repeated measures factors in Proc Mixed; linear and quadratic functions of Block were examined separately via a priori partial interaction contrasts. All analyses made use of unrestricted residual (error) covariance matrices, and an alpha level of .050 was adopted for all F-tests. 2

We chose to constrain our analyses to the first 15 blocks of NPLT data because the rates of strategy shift for all groups declined to a near-asymptote by block 15—especially for prelearned items. By constraining our analyses, we are better able to examine the group differences in strategy use that are most theoretically important: those that occur before strategy use becomes asymptotic for younger adults. Effect sizes are reported using an extension of Cohen's (1988) d statistic that expresses least-squares fitted mean differences as a function of the appropriate pooled error term, $d^* = (M_1 – M_2)/\mathrm{SQRT}(\text{pooled variance estimate})$; in this case the pooled variance estimate was the unweighted average of all error variances for within-subjects factors estimated as random effects by PROC MIXED. This d* statistic may be interpreted as the number of standard deviations that separate the two means; Cohen (1988) suggested benchmarks of 0.2, 0.5, and 0.8 for small, medium, and large effect sizes.

Prelearning

A comparison of age groups revealed that younger adults ($M = 2.78$, $SE = 0.27$) required slightly fewer exposures than older adults ($M = 2.94$, $SE = 0.27$) to reach the specified prelearning criterion, but this effect was not reliable, $F(1, 34) = 0.18$, $p = .670$, $d^* = 0.20$. Separate Age × Prelearning Block × Match analyses were performed on recognition accuracy, confidence, and response time. Typical learning effects were found, such that recognition performance increased with each successive test block ($M_{Block1} = 0.883$, $SE = 0.02$; $M_{Block5} = 0.994$, $SE = 0.02$), $F(4, 13.8) = 6.18$, $p = .005$, $d^* = 0.77$. This increased accuracy coincided with a small but reliable increase in recognition confidence between blocks 1 ($M = 94.47$, $SE = 1.00$) and 5 ($M = 99.84$, $SE = 2.54$), $F(4, 58) = 5.61$, $p < .001$, $d^* = 0.12$. Response times decreased substantially between blocks 1 ($M = 3.23$s, $SE = 0.17$) and 5 ($M = 1.69$s, $SE = 0.17$) as well, $F(4, 58) = 17.20$, $p < .001$, $d^* = 1.29$. Younger adults ($M = 1.61$s, $SE = 0.18$) responded more quickly on average than did older adults ($M = 2.51$s, $SE = 0.19$), $F(1, 34) = 24.85$, $p < .001$, $d^* = 0.74$. Finally, intact items ($M = 1.99$s, $SE = 0.11$) were responded to more quickly than were rearranged items ($M = 2.35$s, $SE = 0.10$), $F(1, 34) = 10.68$, $p = .003$, $d^* = 0.30$, which could indicate the more elaborate processing strategy involved in rejecting rearranged study items (Cohn et al., 2008).

Noun Pair Lookup Task

Self-reported Retrieval Use

We focused on analysis of self-reported retrieval strategy use, given its central relevance to the questions of interest in this study. The remaining trials can be considered reports of visual scanning, either exclusively or in combination with some retrieval use. In the first 15 blocks of practice, older adults reported 12% use of both scanning and retrieval, compared to younger adults' 7%, a reliable difference when tested after conversion to a normal deviate with a probit transformation, $t(66.1) = 3.12$, $p = .003$, $d^* = 0.15$. This effect is consistent with other reports that older adults are somewhat more likely to perform more confirmation-seeking visual searches in the NPLT, even after retrieval use (see Touron et al., 2011). Reports of 'Other' strategies were rare (<1%). Hence a focus on analyzing self-reported retrieval, considering other trials to represent trials involving visual scanning, seemed appropriate.

The clear pattern (see Figure 1) in the data was that the two age groups without prelearning showed typical age differences in reported retrieval adoption, whereas older and younger adults given extensive prelearning did not differ in their reliance on the retrieval strategy across NPLT practice.

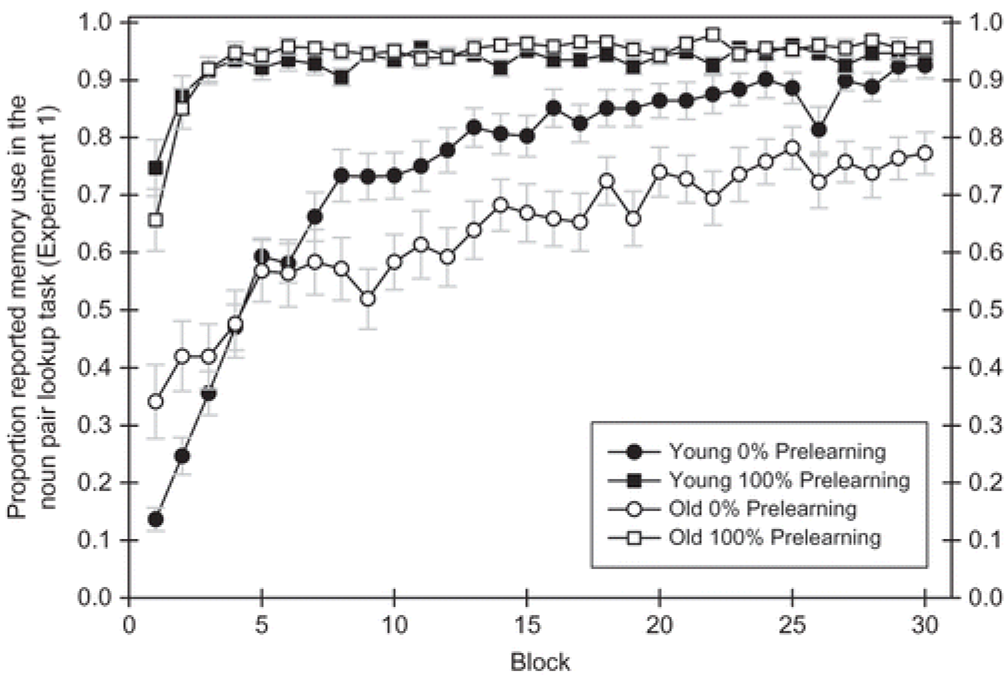

Figure 1. Reported memory use by age, prelearning condition, and block of the noun pair lookup task for Experiment 1.

These observations were supported by the statistical analyses. We used an Age × Prelearning Condition × NPLT Block × Match model to evaluate reported use of the memory strategy. Younger adults ($M = 0.79$, $SE = 0.02$) reported using the retrieval strategy more frequently than did older adults (M = 0.69, SE = 0.02), F(1, 127) = 10.16, p = .002, d* = 0.39. Individuals in the 100% prelearning condition (M = 0.93, SE = 0.02) reported much greater memory use than did those in the 0% prelearning condition (M = 0.55, SE = 0.02), F(1, 127) = 139.88, p < .001, d* = 1.44. More critically, there was a robust age × prelearning interaction, F(1, 103) = 5.29, p = .023. Post-hoc t-tests revealed that while younger and older adults who prelearned the NPs reported similar memory use (M Y = 0.95, SE = 0.03; M O = 0.92, SE = 0.04; t(124) = 0.60, p = .548, d* = 0.10), younger adults who did not prelearn (M = 0.64, SE = 0.03) reported higher memory use than older adults in the same experimental condition (M = 0.46, SE = 0.03), t(130) = 4.07, p < .001, d* = 0.67.

Proportional memory use was on average higher for intact (M = 0.77, SE = 0.02) than for rearranged NPs (M = 0.71, SE = 0.02), F(1, 103) = 10.00, p = .004, though this effect was modest in size, d* = 0.22. Further analysis revealed that this effect was reliable for unprelearned items (M Intact = 0.60, SE = 0.02; M Rearranged = 0.50 SE = 0.03; t(107) = 4.05, p < .001, d* = 0.39) but not for prelearned items (M Intact = 0.94, SE = 0.03; M Rearranged = 0.93 SE = 0.03; t(99.5) = 0.54, p = .589, d* = 0.06), leading to a modest Prelearning Condition × Match interaction, F(1, 103) = 5.62, p = .020.

Reported memory use increased with practice, F(14, 92.6) = 18.06, p < .001. This strategic shift between the first (M = 0.43, SE = 0.03) and 15th block of practice (M = 0.86, SE = 0.02) is associated with a robust effect size, d* = 1.59. As expected, a smaller strategy shift was evident for those who prelearned (M Block 1 = 0.68, SE = 0.04; M Block 15 = 0.98, SE = .03; d* = 1.10) than for those who did not (M Block 1 = 0.19, SE = 0.05; M Block 15 = 0.75, SE = 0.03; d* = 2.08), F(14, 92.6) = 8.82, p < .001, reflecting a higher initial level of memory use for prelearned items. 3 A small but statistically reliable Match × Block interaction, F(14, 102) = 2.51, p < .005, reflected a larger strategy shift for rearranged (M Block 1 = 0.40, SE = 0.04; M Block 15 = 0.84, SE = 0.02; d* = 1.64) than intact items (M Block 1 = 0.47, SE = 0.04; M Block 15 = 0.88, SE = 0.02; d* = 1.54).

Additional a priori contrasts were computed in order to test for effects related to linear and quadratic functions of time (i.e., Block) on shifting to the memory retrieval strategy. A reliable linear effect of Block was found, t(79) = 8.74, p < .001, reflecting greater retrieval use with practice. A reliable quadratic effect of Block was also found, t(79) = –2.35, p = .021, reflecting a transition from scanning to memory that slows over time as participants learn the NPs more thoroughly. Age × Linear block and Prelearning × Linear block interactions were also found, F(1, 76) = 10.65, p = .005, and F(1, 76) = 36.62, p < .001, respectively, reflecting steeper slopes and a lower starting point (i.e., greater room for improvement) for older adults and unprelearned groups. Finally, an Age × Prelearning × Linear block interaction, F(1, 76) = 5.14, p = .026 resulted from a slower transition to memory use for unprelearned groups in general—and especially for the older adult unprelearned group. As can be seen in Figure 1, the retrieval behavior of the older adults with prelearning was indistinguishable from younger adults who had prelearned the pairings, while the memory use of older adults who did not prelearn the pairings lagged behind that of younger adults in the same experimental condition. Thus, extensive prelearning of the NPs overcame the RA seen in older adults who did not undergo prelearning.

Response Times

Figure 2 shows the NPLT RT data as a function of blocks of practice, collapsed over the Match factor. As in our earlier work, older adults without prelearning showed slower improvement in RT as a function of practice, although the switch to retrieval resulted in greater overall RT improvement. In contrast, both older and younger adults given prelearning showed well-ordered RT practice functions that seemed to be more qualitatively similar.

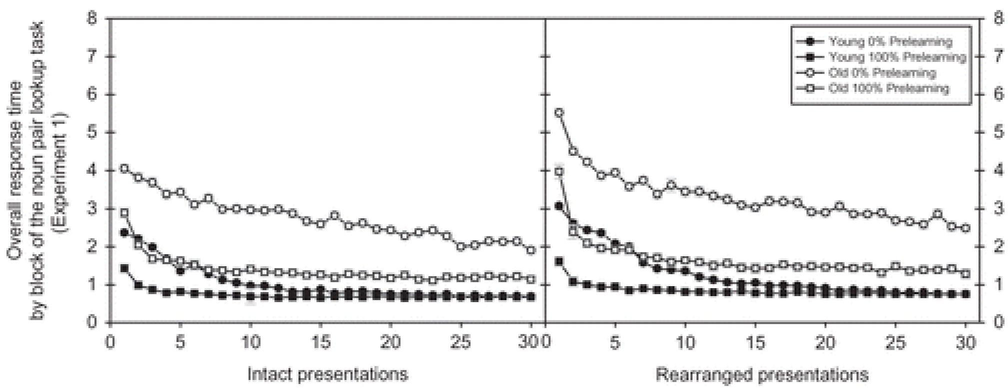

Figure 2. Overall response time by age, prelearning condition, match, and block of the noun pair lookup task for Experiment 1.

An Age × Prelearning Condition × NPLT Block × Match mixed model analysis was performed first to examine overall RT patterns. There were reliable main effects for all factors, but we focus on the critical interactions, especially those involving practice effects. The analysis revealed a reliable age × prelearning interaction, $F(1, 99.6) = 28.83$, $p < .001$, due to the larger average RT benefit older adults received from prelearning (younger adults: 0% prelearning, $M = 1.57$s, $SE = 0.10$; 100% prelearning, $M = 0.97$s, $SE = 0.11$; $d^* = 0.58$; older adults: 0% prelearning, $M = 3.56$s, $SE = 0.09$; 100% prelearning, $M = 1.87$s, $SE = 0.11$; $d^* = 1.63$). Response times decreased with practice, $F(1, 105) = 25.27$, $p < .001$, and the effect was quite substantial in size, $d^* = 1.58$. This practice effect was larger for those who did not experience prelearning ($M_{Block1} = 3.78$s, $SE = 0.13$; $M_{Block15} = 2.02$s, $SE = 0.90$; $d^* = 1.70$) than for those who did ($M_{Block1} = 2.67$s, $SE = 0.15$; $M_{Block15} = 1.15$s, $SE = 0.10$; $d^* = 1.45$), $F(1, 105) = 3.62$, $p < .001$, reflecting the benefit of switching from scanning to retrieval. As during prelearning, intact items ($M = 1.80$s, $SE = 0.05$) were responded to more quickly than were rearranged items ($M = 2.19$s, $SE = 0.07$), $F(1, 149) = 39.69$, $p < .001$, $d^* = 0.37$. Finally, RTs declined more for rearranged items ($M_{Block1} = 3.66$s, $SE = 0.13$; $M_{Block15} = 1.71$s, $SE = 0.09$; $d^* = 1.87$) than for intact items ($M_{Block1} = 2.80$s, $SE = 0.11$; $M_{Block15} = 1.46$s, $SE = 0.71$; $d^* = 1.28$) over time, $F(14, 133) = 1.91$, $p = .031$, consistent with past research showing earlier response facilitation for intact pairings of items and slower adaptation to rearranged pairings (e.g., Hertzog & Touron, 2011).

An Age × Prelearning Condition × NPLT Block × Reported Strategy mixed model analysis was also performed on overall RT. As would be expected from earlier work with the NPLT (e.g., Touron & Hertzog, 2004a, 2004b), scanning RTs (M = 3.43s, SE = 0.04) were slower than retrieval RTs (M = 1.72s, SE = 0.03), $F(1, 167) = 487.16$, $p < .001$, $d^* = 0.42$.

In order to highlight the effects of prelearning on retrieval efficiency, we focused only on the RTs for reported retrieval trials from this point forward. An Age × Prelearning Condition × NPLT Block × Match analysis revealed that memory fluency was greater for younger (M = 1.11s, SE = 0.02) than older adults (M = 2.43s, SE = 0.02), $F(1, 823) = 1781.06$, $p < .001$, $d^* = 0.52$. One can see the great improvement in response efficiency afforded by the memory strategy—especially for older adults (see Figure 3). Those who prelearned the NPs (M = 1.32s, SE = 0.02) responded faster than those who did not (M = 2.25s, SE = 0.02), $F(1, 823) = 832.32$, $p < .001$, $d^* = 0.36$. Prelearning had a greater effect on older adults' memory fluency (0% Prelearned: M = 3.20s, SE = 0.03; 100% Prelearned: M = 1.73s, SE = 0.03; d^* = 0.57) than on that of younger adults (0% Prelearned: M = 1.30s, SE = 0.04; 100% Prelearned: M = 0.92s, SE = 0.03; d^* = 0.15), $F(1, 823) = 291.58$, $p < .001$. Fluency increased with practice (M_{Block1} = 2.93s, SE = 0.13; $M_{Block15}$ = 1.43s, SE = 0.05), $F(14, 749) = 26.09$, $p < .001$, $d^* = 0.58$, and this effect was larger for older adults (M_{Block1} = 4.05s, SE = 0.15; $M_{Block15}$ = 2.01s, SE = 0.07; d^* = 0.79) than younger adults (M_{Block1} = 1.82s, SE = 0.20; $M_{Block15}$ = 0.86s, SE = 0.07; d^* = 0.37), $F(14, 749) = 2.82$, $p < .001$. The effect was also larger for unprelearned items (M_{Block1} = 3.68s, SE_{Block1} = 0.22; $M_{Block15}$ = 1.80s, SE = 0.07; d^* = 0.73) than for prelearned items (M_{Block1} = 2.18s, SE = 0.14; $M_{Block15}$ = 1.07s, SE = 0.07; d^* = 0.43), $F(14, 749) = 3.13$, $p < .001$. Younger adult RTs approached convergence at block 15 of the task, while those of older adults did not. Also, older adults who did not prelearn were slower than those who did, and this is especially true early in practice. This pattern aligns with the argument of Cerella et al. (2006); it may be that part of the reason older adults shift to retrieval more slowly despite accurate memory use is that retrieval is a longer, more variable process for older than younger adults.

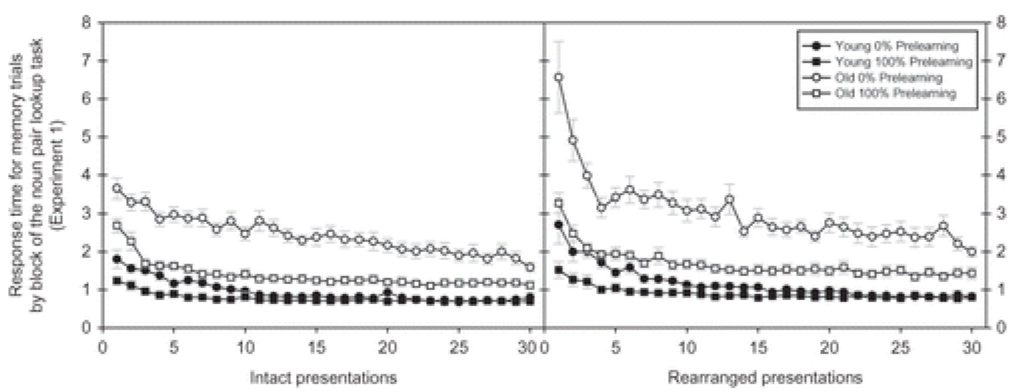

Figure 3. Response time for reported memory trials by age, prelearning condition, match, and block of the noun pair lookup task for Experiment 1.

Consistent with the idea that greater variability in RT may result from mixing intact and rearranged items at test, intact items (*M* = 1.59s, *SE* = 0.02) were responded to faster than were rearranged items (*M* = 1.98s, *SE* = 0.02), $F(1, 823) = 147.08$, $p < .001$, $d^* = 0.25$, and the difference was somewhat larger for older ($M_{Intact} = 2.19$s, *SE* = 0.03;$M_{Rearranged} = 2.73$s, *SE* = 0.03; $d^* = 0.21$) than younger adults ($M_{Intact} = 0.99$s, *SE* = 0.03; $M_{Rearranged} = 1.22$s, *SE* = 0.03; $d^* = 0.09$), $F(1, 823) = 23.33$, $p < .001$. The difference was also greater for unprelearned items ($M_{Intact} = 1.98$s,*SE* = 0.03; $M_{Rearranged} = 2.52$s, *SE* = 0.03; $d^* = 0.21$) than prelearned items ($M_{Intact} = 1.20$s, *SE* = 0.03; $M_{Rearranged} = 1.44$s, *SE* = 0.03; $d^* = .10$), $F(1, 823) = 21.78$, $p < .001$. Indeed, the most surprising aspect of the data was the long RTs early in practice for reported retrieval times for older adults who did not have prelearning, especially for rearranged items. We comment on the interpretation of this pattern in the Discussion.

A reliable Age × Prelearning Condition × Match interaction reflected the benefits of prelearning, which include recognizing correctly paired items and rejecting incorrectly paired items more quickly. This effect is larger for older adults (0% intact: *M* = 2.82s, *SE* = 0.04; 0% rearranged: *M* = 3.58s, *SE* = 0.05; $d^* = 0.29$; 100% intact: *M* = 1.56s, *SE*= 0..04; 100% rearranged: *M* = 1.89s, *SE* = 0.04; $d^* = 0.13$) than younger adults (0% intact: *M* = 1.14s, *SE* = 0.05; 0% rearranged: *M* = 1.46s, *SE* = 0.05; $d^* = 0.12$; 100% intact: *M* = 0.84s, *SE* = 0.04; 100% rearranged: *M* = 1.00s,*SE* = 0.04; $d^* = 0.06$), $F(1, 823) =4.75$, $p = .030$. Consistent with ALD, it appears that the memory strategy was invoked more slowly and more variably for older adults. Likewise, older adults without prelearning failed to reach the high degree of consistent fluency of older adults who prelearned the items. These older adults appeared to be much more similar to younger adults in terms of memory use.

Finally, *a priori* contrasts were generated to examine the nature of the change in RT based using linear and quadratic functions of block. A reliable linear effect was found for block, $t(79) = –3.11$, $p = .003$, indicating a decrease in average RT over time. This rate of decrease was greater for older adults, given their greater room for improvement,$F(1, 76) = 7.58$, $p = .007$. The rates of decrease were more similar between younger adult groups than older adult groups, $F(1, 76) = 7.00$, $p = .010$. A reliable quadratic Block effect was found, $t(1, 79) = –2.53$, $p = .013$, and it was complicated by an interaction with age, $F(1, 76) = 11.47$, $p = .001$, as well as a Block × Age × Prelearning interaction,$F(1, 76) = 5.15$, $p = .026$. The rate at which asymptotic RT is reached is similar for both younger adult groups and older adults who prelearned. However, older adults who did not prelearn were unable to reach the same level of absolute performance as the older adults who did, and their retrieval fluency increased more slowly than that of any other group.

Accuracy

We also analyzed the accuracy data on NPLT trials, and findings were consistent with previous work in the NPLT (e.g.,Touron et al., 2007). It is of note that younger adults (*M* = 0.95, *SE* = 0.01) exhibited a reliably lower proportion of accurate responses than did older adults (*M* =

0.97, *SE* = 0.01), *F*(1, 1045) = 7.13, *p* = .007, though the size of the effect is very small, *d** = 0.13. Accuracy levels did not differ between age groups for retrieval-based responses in the 100% Prelearned groups (*M* = 0.97, *SE* = 0.01 for both ages, *t*(1202) = –1.31, *p* = .191, *d** = 0.05), or the 0% Prelearned groups (Younger adults: *M* = 0.93, *SE* = 0.01; Older adults: *M* = 0.95, *SE* = 0.01; *d** = 0.09), *F*(1, 1045) = 0.74, *p* = .391. A direct comparison of accuracy levels for scanning trials was not possible. Due to the rapid adoption of retrieval-based responding, mean levels of scanning accuracy for a given task block were in some cases based on five or fewer responses within a given Age × Prelearning Condition group or were incalculable.

Discussion

The stringent prelearning criterion employed in Experiment 1 increased the utilization of memory-based responding in both younger and older adults, affecting both the absolute level of retrieval use and the speed at which the transition was made from scanning to retrieval in the NPLT. After prelearning, both older and younger adults did not immediately manifest the highest possible levels of retrieval-based responding. There was an initial warm-up phase in both age groups that probably involved a general form of strategic adaptation to the viability of using retrieval instead of scanning. This effect dissipated after a few trials with each noun pair, at a similar rate for both young and older adults.

The benefits of prelearning were especially large for older adults, as reflected in their overall levels of memory use, their faster memory-based RTs, and the speed and degree to which the memory strategy was adopted. The typical pattern of age differences in retrieval shift observed in the standard (0% prelearning) NPLT condition were fully eliminated by the prelearning manipulation. Even when retrieval was reported in the standard condition, older adults showed slower RTs for rearranged pairs. This difference interacted with prelearning, minimizing RT differences between intact and rearranged pairs. Thus, one possible benefit of prelearning is that the resulting level of learning makes it possible for older adults to reject rearranged pairs more efficiently, perhaps by creating sufficient recollective experiences to afford recall-to-reject strategies (e.g., Cohn et al., 2008; Gallo, Bell, Beier, & Schacter, 2006). This effect may, in turn, allow older adults to rely on the retrieval strategy without excessive risk of errors (Hertzog & Touron, 2011).

It was interesting that older adults' reported retrieval trials were characterized by rather long RTs early in practice, especially for rearranged pairs. It is important to remember that these data were generated by relatively few reported retrieval trials (see Figure 1). Reported retrieval trials early in practice may involve a deliberate effort to attempt the retrieval strategy after priming by the strategy report, with the retrieval search taking considerable time when the memory trace is not well-established. Moreover, it is possible that early reported retrievals are a mixture of scanning and retrieval strategies that were for some reason not identified as ‘both’ strategies by participants. 4 Nevertheless, it is clear that RTs for reported retrieval trials are reduced dramatically with practice for older adults, but still generate considerable variability well into the NPLT, especially when items were not prelearned.

In general, then, it appears that the more stringent prelearning criterion enhanced memory fluency to the degree required to eliminate the delayed retrieval shift in older adults, while also speeding retrieval shift (to a lesser degree) in younger adults. These findings differ from those of Touron and Hertzog (2004b), which utilized a less stringent prelearning criterion and failed to speed older adults' responding to the degree seen here or equate younger and older adults on the degree of retrieval-based responding in the NPLT. The current data are consistent with predictions from an ALD account, which stipulates that extensive practice (i.e., prelearning) compensates for the slower rates of learning typical of older adults, equating the age groups in adoption of a memory-based response strategy (Cerella et al., 2006).

EXPERIMENT 2

The stricter learning criterion in Experiment 1 resulted in a quick retrieval shift for prelearned items by older adults. Experiment 2 was designed to contrast the RA and ALD hypotheses by administering 0, 50, and 100% prelearning conditions. Older adults who prelearned 50% of the NP stimuli should either display a more universal adoption of a memory-based response strategy for prelearned items (consistent with ALD) or differential strategic implementation depending on whether prelearned items are mixed with unstudied items (consistent with RA). The RA hypothesis predicts a context effect, such that older adults in the 50% prelearning condition should show delayed retrieval shift for prelearned items relative to the 100% condition, when all items are prelearned. When individuals are uncertain prior to trial onset about whether the association is known, older adults were expected to show increased use of the scanning strategy for prelearned items. The ALD hypothesis, however, predicts an elementary instance-learning pattern (e.g., Logan, 1988), with equivalent and early memory use for prelearned items by older adults regardless of whether or not they are mixed with new (unstudied) or other prelearned items.

Method

Design

The experiment was a 2 (Age: Young, Old) × 2 (Noun Pair Exposure: 0% Prelearning, 50% Prelearning, 100% Prelearning) between-subjects design.

Participants

Using the same age criteria, sampling methods, and compensation as in Experiment 1, 57 younger adults and 56 older adults participated. Participant characteristics are presented in Table 1. Approximately one-third of the participants in each age group were tested within each prelearning condition. No participants were removed from our analyses as a result of the basic health exclusions. One younger adult and 12 older adults were not included in the following analyses due to a failure to meet the prelearning criterion outlined for Experiment 1.

Materials and Procedure

The NPLT was identical to that of Experiment 1, except that it consisted of 20 blocks of practice instead of 30 and no response time estimates were collected. This was because the learning effects on variables of interest were viewed as being rather minor after block 20 in Experiment 1. Unlike in Experiment 1, all participants completed a prelearning task similar to that used in Experiment 1 prior to completing the NPLT. Participants who experienced retrieval use during prelearning might have been more likely to engage in its use during the NPLT due to mere behavioral inertia, maintaining a consistent processing approach to the task. Hence having all groups prelearn the stimuli, even when prelearned items would not be used during skill acquisition, equated groups on prelearning experience and whatever influence that could have on strategic behavior in the NPLT. Participants learned a random set of 12 items drawn from a larger set of 24. Participants in the 0% prelearning condition were given 12 unstudied items in the NPLT, while those in the 50% condition were given 6 random pairs from the prelearning phase and 6 random unstudied pairs, and those in the 100% prelearning condition were shown all 12 prelearned pairs in the NPLT.

Results

Prelearning

Unlike in Experiment 1, older adults ($M = 3.34$, $SE = 0.17$) required significantly more exposures to learn the items than did younger adults ($M = 2.57$, $SE = 0.16$), $F(1, 116) = 10.17$, $p = 0.002$, $d^* = 0.59$. Age × Prelearning Condition × Block × Match comparisons of response accuracy, RT, and confidence revealed the following effects. Younger adults ($M = 0.98$, $SE = 0.01$) were slightly more accurate than were older adults ($M = 0.95$, $SE = 0.01$), $F(1, 179) = 8.49$, $p = .004$, $d^* = 0.21$. Recognition accuracy increased with practice ($M_{\text{Block1}} = 0.89$, $SE = 0.01$) to 4 ($M_{\text{Block4}} = 0.97$, $SE = 0.01$), $F(3, 122) = 25.61$, $p < .001$, $d^* = 0.51$, and this effect was larger for older adults ($M_{\text{Block1}} = 0.86$, $SE = 0.01$; $M_{\text{Block4}} = 1.00$, $SE = 0.01$; $d^* = 0.98$) than for younger adults ($M_{\text{Block1}} = 0.93$, $SE = 0.02$; $M_{\text{Block4}} = 1.00$, $SE = 0.02$; $d^* = 0.49$), reflecting greater room for improvement, $F(3, 122) = 2.71$, $p = .048$.

Younger adults ($M = 1.77$s, $SE = 0.09$) responded more quickly than did older adults ($M = 2.95$s, $SE = 0.08$), $F(1, 130) = 95.21$, $p < .001$, $d^* = 0.56$, and average RT decreased with practice ($M_{\text{Block1}} = 3.46$s, $SE = 0.12$; $M_{\text{Block4}} = 1.86$s, $SE = 0.06$), $F(3, 77.8) = 81.37$, $p < .001$, $d^* = 0.41$, with older adults' RTs ($M_{\text{Block1}} = 4.34$s, $SE = 0.16$; $M_{\text{Block4}} = 2.28$s, $SE = 0.07$, $d^* = 0.97$) benefitting more from practice than those of younger adults ($M_{\text{Block1}} = 2.58$s, $SE = 0.17$; $M_{\text{Block4}} = 1.43$s, $SE = 0.10$, $F(3, 77.8) = 5.73$, $p = .001$, $d^* = 0.54$). Finally, younger adults ($M = 0.98$, $SE = 0.01$) were slightly more confident in their recognition responses than were older adults ($M = 0.95$, $SE = 0.01$), $F(1, 230) = 10.88$, $p = .001$, $d^* = 0.18$, with average response confidence increasing with practice (M_{Block1} = 90.77, SE = 0.86; M_{Block4} = 99.94, SE = 1.10), $F(3, 106) = 28.59$, $p < .001$, $d^* = 0.51$.

Noun Pair Lookup Task5

Self-reported Retrieval Strategy Use

Figure 4 shows the retrieval strategy self reports across blocks of practice. It shows clearly that there was a major separation of the 0 and 100% prelearning data, replicating Experiment 1. More important, however, was the fact that the data for prelearned items in the 50% prelearning condition did not simply follow the 100% prelearning function for either age group. These outcomes indicated effects of strategic set, in which the mixture of unlearned and prelearned items altered individuals' strategic approach to the task. Most important, older adults' retrieval use for prelearned items in the 50% prelearned condition (open upward-pointing triangles in Figure 4) lagged substantially behind older adults' retrieval use in the 100% prelearning condition (open squares in Figure 4), and never achieved the same asymptote. This outcome is critical evidence favoring the RA hypothesis.

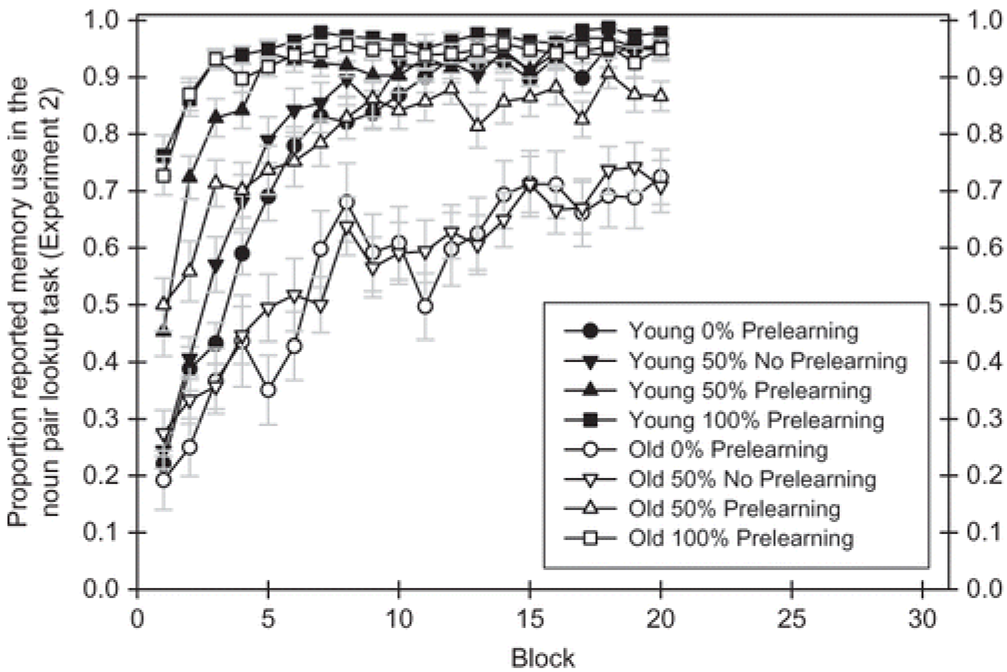

Figure 4. Reported memory use by age, prelearning condition, and block of the noun pair lookup task for Experiment 2.

These general observations were supported by results from Age × Prelearning Condition × NPLT Block × Match mixed model analyses performed on reported memory use with NPLT. In lieu of examining a full factorial model, we favored*a priori* contrasts that focused on the interactions relevant to the RA effect. We compared memory use for unstudied items in the 0% prelearning and 50% prelearning groups and, separately, compared prelearned items in the 50 and 100%

prelearning groups. Main effects were statistically reliable, but we focus on the interactions relevant to the RA effect. An age × prelearning condition interaction for reported memory use was reliable for prelearned items, $F(1, 147) = 9.89$, $p = .002$, but not for unprelearned items, $F(1, 142) = 0.40$, $p = .526$. For prelearned items, a large disparity in reported retrieval use was evident for older adults ($M_{50\%} = 0.75$, $SE = 0.02$; $M_{100\%} = 0.94$, $SE = 0.02$; $t(149) = 7.56$, $p < .001$, $d^* = 0.82$), but only a small effect was seen for younger adults ($M_{50\%} = 0.86$, $SE = 0.02$; $M_{100\%} = 0.94$, $SE = 0.02$; $t(146) = 2.84$, $p < .001$, $d^* = 0.35$). Adults in the 100% prelearning condition reported similar levels of retrieval use, $t(145) = 0.01$, $p = .994$, $d^* = 0.00$, whereas older adults in the 50% condition were at a retrieval disadvantage compared to younger adults $t(149) = 4.41$, $p < .001$, $d^* = 0.48$, indicative of older adults' RA. For unprelearned items, levels of memory use did not vary reliably by prelearning condition for younger adults ($M_{0\%} = 0.75$, $SE = 0.03$; $M_{50\%} = 0.77$, $SE = 0.03$; $t(134) = –0.56$, $p = .574$, $d^* = 0.11$) or older adults ($M_{0\%} = 0.43$, $SE = 0.09$; $M_{50\%} = 0.49$, $SE = 0.03$), $t(149) = –1.38$, $p = .169$, $d^* = 0.17$. Older adults who were well-acquainted with the retrieval strategy as a consequence of prelearning items also reported using this strategy more frequently for unprelearned items, thereby partially overcoming RA.

A Prelearning Condition × Block interaction manifested for prelearned items, $F(14, 117) = 3.46$, $p < .001$, but not for unprelearned items, $F(14, 105) = 1.42$, $p = .156$. Likewise, an important Age × Prelearning Condition × block interaction was detected only for prelearned items, $F(14, 117) = 1.82$, $p = 043$. Whereas reported memory use for prelearned items in the 50 and 100% prelearning conditions became highly similar early into practice for younger adults (Block 5: $M_{50\%} = 0.94$, $SE = 0.03$; $M_{100\%} = 0.95$, $SE = 0.03$; $t(133) = 0.21$, $p = .837$, $d^* = .04$), retrieval use was much less frequent for prelearned items by older adults in the 50% condition ($M_{Block5} = 0.69$, $SE = 0.03$) compared to the 100% condition ($M_{Block5} = 0.94$, $SE = 0.03$), $t(136) = 6.56$, $p < .001$, $d^* = 1.08$, consistent with the RA hypothesis. Despite achieving the same learning criterion for these items prior to the NP task, older participants were less willing to rely on their memories for prelearned items when they were mixed with unstudied items. This effect falsifies the ALD hypothesis, which posits that the patterns of memory use for prelearned items should be equivalent across the two conditions.

Memory strategy use across blocks for unstudied items in the 50% condition exactly paralleled retrieval use for individuals in the 0% prelearning condition, where all items were unstudied. In the aggregate, the retrieval strategy was used similarly for unstudied items in the 0 and 50% conditions (see above for the relevant *F*-test), and showed similar practice-related increases over time (see Figure 4). Indeed, for older adults, the two functions (open circles and downward-pointing triangles in Figure 4) were overlapping and indistinguishable. *A priori* contrasts involving linear and quadratic functions of Block supported these statements. Reported retrieval use did increase over time for unprelearned items, $t(76) = 13.46$, $p < .001$, and the Age × Block interaction was reliable, $F(1, 73) = 19.22$, $p < .001$, indicating that the rates of memory use changed more quickly for younger than older adults. However, no Age × Prelearning × Block interaction was found, which indicates that both younger and older adults' rates of retrieval adoption were both similar between prelearning conditions for unprelearned items.

NPLT Response Times

We again focused on memory retrieval RTs, given the substantial initial retrieval use in the 100% prelearning condition, using *a priori* contrasts like those used in Experiment 1. Separate Age × Prelearning Condition × Block × Match analyses were performed on RT for reported memory trials for prelearned and unprelearned items (see Figure 5). Younger adults responded faster than older adults on average for both prelearned (M_{Y} = 1.20s, *SE* = 0.02; M_{O} = 1.95s, *SE* = 0.02, *d** = 1.14) and unprelearned items (M_{Y} = 1.50s, *SE* = 0.03; M_{O} = 2.54s, *SE* = 0.03, *d** = 1.58),*F*(1, 2212) = 755.91, $p < .001$, and *F*(1, 1739) = 605.9, $p < .001$, respectively. Responses to prelearned items in the 100% condition (*M* = 1.38s, *SE* = 0.02) were faster than those to prelearned items in the 50% condition (*M* = 1.77s,*SE* = 0.02), *F*(1, 2212) = 210.07, $p < .001$, *d** = 0.59. Unstudied items in the 50% prelearning condition (*M* = 1.96s,*SE* = 0.03) were responded to as slowly as the unstudied items in the 0% condition (*M* = 2.09s, *SE* = 0.03), *F*(1, 1739) = 8.38, *p* = .055, *d** = 0.11

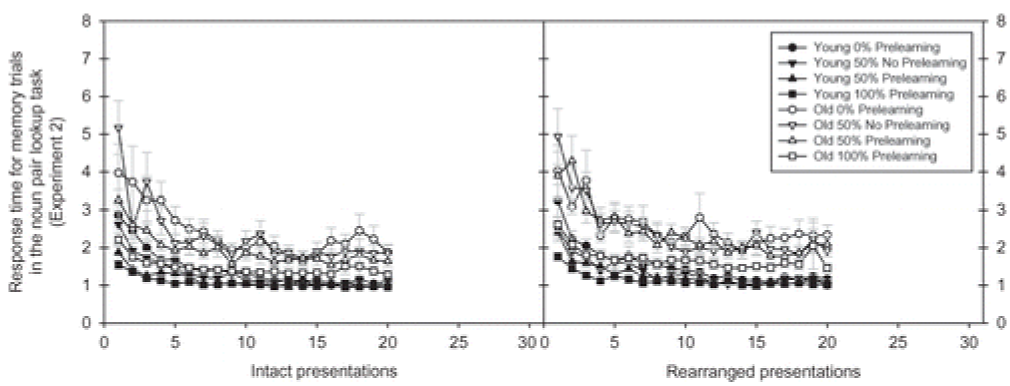

Figure 5. Response time for reported memory trials by age, prelearning condition, match, and block of the noun pair lookup task for Experiment 2.

The Age × Prelearning Condition interaction was reliable only for prelearned items, *F*(1, 2212) = 210.07, $p < .001$, indicating that RTs differed less between younger groups ($M_{50\%}$ = 1.26s, *SE* = 0.03; $M_{100\%}$ = 1.14s, *SE* = 0.03; *d** = 0.18) than older groups ($M_{50\%}$ = 2.29s, *SE* = 0.03; $M_{100\%}$ = 1.61s, *SE* = 0.03, *d** = 1.04). The consistent memory use that is evident in both younger adult groups and older adults who prelearned all items is associated with highly fluent retrieval, with older adults receiving a larger benefit. Memory fluency increased with practice for prelearned items (M_{Block1} = 2.45s, *SE* = 0.06; $M_{Block15}$ = 1.32s, *SE* = 0.05), *F*(14, 2212) = 33.36, $p < .001$, *d** = 1.72, and unprelearned items (M_{Block1} = 3.67s, *SE* = 0.12; $M_{Block15}$ = 1.58s, *SE* = 0.07), *F*(14, 1739) = 36.31, $p < .001$, *d** = 2.58. This effect was larger for older adults for prelearned items (M_{Block1} = 3.00s, *SE* = 0.08; $M_{Block15}$ = 1.65s, *SE* = 0.71; *d** = 2.06; Young: M_{Block1} = 1.90s, *SE* = 0.08; $M_{Block15}$ = 0.99s, *SE* = 0.08; *d** = 1.39), *F*(14, 2212) =

2.96, $p < .001$, and unprelearned items (Young: $M_{Block1} = 2.80$s, $SE = 0.15$; $M_{Block15} = 1.10$s, $SE = 0.09$; $d^* = 2.03$; Old: $M_{Block1} = 4.53$s, $SE = 0.19$; $M_{Block15} = 2.06$s, $SE = 0.11$; $d^* = 2.95$), $F(14, 1739) = 2.85$, $p < .001$.

Fluency improvements were smaller for those who prelearned all items ($M_{Block1} = 2.04$s, $SE = 0.08$; $M_{Block15} = 1.22$s, $SE = 0.07$; $d^* = 1.25$) than those who prelearned half of the items ($M_{Block1} = 2.86$s, $SE = 0.07$s; $M_{Block15} = 1.42$s, $SE = 0.07$; $d^* = 2.19$), $F(14, 2212) = 3.87$, $p < .001$. However, fluency improvements did not differ between 0% ($M_{Block1} = 3.87$s, $SE = 0.15$; $M_{Block15} = 1.60$s, $SE = 0.10$; $d^* = 2.71$) and 50% unprelearned items ($M_{Block1} = 3.81$s, $SE = 0.17$; $M_{Block15} = 1.60$s, $SE = 0.10$; $d^* = 2.64$), $F(14, 1739) = 0.62$, $p = .849$. The Age × Prelearning Condition × Block interaction failed to reach statistical significance for either prelearned items, $F(14, 2212) = 1.57$, $p = .081$, or unprelearned items, $F(14, 1739) = 1.04$, $p = .413$. Gains in retrieval fluency during the NPLT were relatively small for prelearned items, relatively large for unprelearned items, and similar across age groups for each item type.

Intact NPs ($M = 1.45$s, $SE = 0.02$) were generally responded to faster than were rearranged items ($M = 1.70$s, $SE = 0.02$) for both prelearned, $F(1, 2212) = 87.61$, $p < .001$, $d^* = 0.38$, and unprelearned items ($M_{Intact} = 1.97$s, $SE = 0.03$; $M_{Rearranged} = 2.08$s; $SE = 0.03$), $F(1, 1739) = 7.29$, $p = .007$, $d^* = 0.13$. No other reliable main effects or interactions were found for unprelearned items (all $p > .200$), so the following relationships describe only prelearned items. The Age × Match interaction was reliable, $F(1, 2212) = 26.49$, $p < .001$. Younger adult responses to intact items ($M = 1.14$s, $SE = 0.03$) were faster than their responses to rearranged items ($M = 1.26$s, $SE = 0.03$), $t(2212) = –2.93$, $p < .001$, $d^* = 0.18$, which were faster than older adults' responses to intact items ($M = 1.75$s, $SE = 0.97$), $t(2212) = –12.93$, $p < .001$, $d^* = 0.75$, and older adult responses to rearranged items were the slowest of all ($M = 2.15$s, $SE = 0.03$), $t(2212) = –10.45$, $p < .001$, $d^* = 0.61$ (when compared to older adults' responses to intact items). A Prelearning Condition × Match interaction, $F(1, 2212) = 12.75$, $p < .001$, and an Age × Prelearning Condition × Match interaction, $F(1, 2212) = 4.42$, $p = .036$, reflected different average fluencies between all Prelearning Condition × Match cells for older adults ($p < .001$ for all comparisons), while, for younger adults, only the 50% prelearned rearranged items differed from the others ($p > .16$ for comparisons between similar items, while $p < .005$ for comparisons between those cells and 50% rearranged items).

Finally, *a priori* contrasts were constructed in order to examine fluctuations in memory fluency during the NPLT. Only main effects of linear and quadratic Block were found for prelearned items, $t(81) = –7.78$, $p < .001$, and unprelearned items, $t(81) = –6.78$, $p < .001$, respectively, reflecting higher retrieval use with practice with similar improvements across time for different Age × Prelearning Condition groups. Prelearning offered older adults the opportunity to overcome their RA and perform more similarly to younger adults with regard to memory use across blocks for both intact and rearranged items. However, for unprelearned items, several age-related differences were found, with the most relevant being an Age × Block interaction, $F(1.73)$

= 5.68, $p = .020$, which is indicative of the slower average rates of strategy shift for older adults for unprelearned items, even for older adults who prelearned half of the NPs.

Discussion

The memory use data from Experiment 2 indicated that extensive prelearning of all items boosted reported memory use for both younger and older adults, as in Experiment 1. Prelearning also speeded older adults' retrieval times, especially for rearranged items, consistent with an ALD account. However, patterns of memory use for prelearned items were quite different depending upon whether or not these items were mixed with unstudied items during the NPLT. For younger adults, the 50% prelearning condition rapidly converged with the 100% prelearning condition. For older adults, however, the use of memory retrieval on prelearned items in the 50% condition was intermediate between the 0 and 100% prelearning conditions and never reached the asymptote defined by the 100% condition. This pattern of data provides strong evidence for RA that is isolated to the older adult sample; an ALD account alone does not explain our data.

The 50% prelearning condition also resulted in intermediate effects on NPLT RTs. Even when older adults reported memory retrieval, their RTs did not approach the asymptote defined by the 100% prelearning condition. This effect can be interpreted as the consequence of a greater number of scanning trials limiting the influences of repeated retrieval practice on retrieval fluency due to lower frequency of memory strategy use. The longer retrieval times for prelearned items in the 50% condition displayed by older adults, and, to a lesser extent, younger adults, may likewise be interpreted as evidence of the time cost associated with choosing between scanning and retrieving on a trial-by-trial basis. These groups did not differ in retrieval times in the prelearning condition itself. More fluent responses were typical of items in the 100% prelearning condition not only because retrieval use dominated, but also because participants' use of the memory strategy was more automatic, and a lengthy decision process (in the scale of ms) was usually not required after the first few blocks of practice after participants acclimated to the NPLT.

The above results also control for a possible confound in Experiment 1, in that all participants underwent a similar prelearning experience prior to being transferred to the NPLT. Because individuals in the 0% condition had prelearned items that were not used in the NPLT, all groups were equated on whether they experienced the benefits of increasing associative memory strength on retrieval fluency – thereby illustrating the potential usefulness of the memory strategy for fast responses in the NPLT. Inaccurate monitoring of retrieval latencies appears to delay older adults' memory shift in the NPLT (Hertzog et al., 2007). Nevertheless, it appears that mere experience of successfully remembering NP stimuli during prelearning was inadequate to facilitate faster use of the retrieval strategy in the actual NPLT. This was true even for unstudied items in the 50% condition; despite the high memory fluency and degree of retrieval use characteristic of prelearned items in this condition, retrieval use for unstudied items lagged considerably and showed no difference between the 50 and 0% conditions for both age groups.

As a final note, these data again highlight the importance of separating recognition trials (in this case, NPLT trials) by stimulus presentation type. When examining the RTs and retrieval adoption data for participants in the 50% condition different results were found depending on whether or not a given trial consisted of an intact or rearranged test pairing. Such effects were ignored in our earlier work (i.e., Touron & Hertzog, 2004b).

GENERAL DISCUSSION

Performance in the NPLT is facilitated by the transition from a visual scanning strategy to a memory-retrieval strategy. Older adults typically make this retrieval shift much more slowly than younger adults, due at least in part to an age-related ALD. The current research, however, falsifies the hypothesis that a pure ALD can account for age differences in rates of practice-related improvements in the NPLT.

The new, more stringent, prelearning criterion in Experiment 1 eliminated age differences in retrieval shift in the NPLT when all items were prelearned. Experiment 2 made use of this level playing field between younger and older adults by contrasting memory use when prelearned and unstudied pairs were mixed together. An ALD explanation, grounded in instance-theory approaches to skill acquisition (e.g., Cerella et al., 2006) argues that the degree of associative strength achieved by item exposures causes retrieval to be completed faster than scanning, resulting in memory-based responses. By such views, all prelearned items should have manifested similar patterns of retrieval shift regardless of whether or not they were co-presented with unstudied items. Instead, older adults were much slower to adopt a retrieval-based response strategy for prelearned pairs when prelearned and unstudied pairs were shown at test. Even at the end of testing, these 50% prelearned items were not associated with as high a level of memory use as were the 100% prelearned items for our older sample. These results indicate that strategic choice is involved in retrieval shift, and that in the presence of unstudied items, older adults adopt a strategic set that emphasizes scanning over retrieval, even when the degree of prelearning affords the use of memory retrieval as the basis for the NPLT response. This outcome was critical evidence for the RA hypothesis as playing a role in age differences in retrieval shift.

This study adds to the growing evidence of top-down strategic choice mechanisms in elementary skill acquisition tasks (e.g., Bourne et al., 2010; Haider et al., 2005). Such effects do not deny the importance of associative binding mechanisms in acquiring discriminative responses (e.g., Anderson & Lebiere, 1988; Wenke, Nattkemper, Gaschler, & Frensch, 2009), nor do they contradict the important role of associative deficits (e.g., Mutter, Decaro, & Plumlee, 2009) in constraining older adults' skill development in tasks requiring associative learning. Instead, our results simply implicate a role of strategic choice and decision processes in skilled performance (e.g., Lemaire, 2010; White, Cerella, & Hoyer, 2007), one that a mechanistic associative learning view does not countenance (e.g., Onyper et al., 2008).

Older adults' RA in the NPLT has been shown to correlate with delayed automaticity in other kinds of search-detection tasks (Rogers, Hertzog, & Fisk, 2000), and mental arithmetic tasks that also involve algorithm-to-retrieval shifts appear to manifest similar RA (e.g., Touron & Hertzog, 2009). Open questions for future research are whether, when, and why older adults' skill acquisition is delayed or impaired when memory retrieval per se is not a central processing requirement for skilled performance. There are multiple strands of evidence in the literature of older adults manifesting less attention-based training. Research on the psychological refractory period indicates that older adults have greater difficulty overcoming a central processing bottleneck in multiple task environments (Maquestiaux et al. 2010), although there is some evidence that training in multiple task environments does improve older adults' performance (e.g., Bherer et al., 2006; Sit & Fisk, 1999). Delayed perceptual learning has been attributed to conservative executive control behavior in these tasks (Maquestiaux et al., 2010), perhaps due to differences in top-down strategic control (Glass et al., 2000).

Older adults' acquisition of automaticity in visual attention control (elimination of display-size effects in visual search) seems to be intact when simple perceptual discriminations form the basis of an automatic alerting response (Anandam & Scialfa, 1999). Likewise, recently completed work from Touron's lab suggests no age-related decline in strategic shift in a modified version of Haider and Frensch's (1996) perceptual learning task that does not involve memory retrieval (Frank, Touron, & Hertzog, 2011). However, work by Fisk, Rogers, and associates has indicated that older adults' acquisition of automaticity in attentional control is impaired when the search elements involve semantically categorizable nouns (e.g., Rogers, Fisk, & Hertzog, 1994). In general, then, impaired automaticity in attentional control tasks does not seem to be generically due to RA, although different types of top-down strategic mechanisms may play a role. It could be the case that strategic factors are most likely to impede older adults' skill acquisition when explicit reliance on a memory retrieval strategy is required.

Age-related RA in skill acquisition tasks such as the NPLT or mental arithmetic tasks may reflect older adults' perceptions that (1) performance will not benefit from using the retrieval strategy or (2) the risks of making errors in the task when relying on memory retrieval are too great. The latter case may be closely linked to older adults' beliefs that their memory has declined and cannot be counted upon (Lineweaver & Hertzog, 1998; Touron & Hertzog, 2004a). They may also not wish to risk a loss of self-efficacy and self-esteem should attempted memory use fail to produce a desired level of performance (see West, Thorn, & Bagwell, 2003). However, older adults may also generally be more cautious in performance contexts, being less willing to produce errors when a means of insuring accurate responding is available (e.g., Botwinick, 1984; see Hertzog, 2008).

Although the present study provides experimental evidence of top-down strategic control in NPLT, and of retrieval reluctance by older adults when items are not prelearned, we advise caution in generalizing the prelearning outcomes to other skill acquisition task contexts. In particular, the elimination of age differences in retrieval use by older adults in the 100%

prelearning condition should not be taken as indicating that, in general, slower skill acquisition by older adults can routinely be overcome by prelearning relevant information. This effect probably applies only to the class of skill acquisition tasks that can be characterized as involving algorithm-to-retrieval shifts, and even then may not generalize to more complicated retrieval-based skills. When there are complex motor sequences to be mastered, for instance, it is difficult to imagine how prelearning item content per se might benefit skill acquisition. The prelearning manipulation can be viewed, however, from the lens of single versus multiple-task training (e.g., Bherer et al., 2006). There is evidence that older adults sometimes benefit from focused single-task training, possibly because of reduced demands on the central executive to learn specific processes while also compiling a complex task algorithm (e.g., Sit & Fisk, 1999).

In summary, volitional strategic choice in skill acquisition contexts can facilitate or hinder learning. It also contributes to individual differences in the degree of skill attainment (Gray & Fu, 2004; Haider et al., 2005; Rogers et al., 2000; Sit & Fisk, 1999). This study also illustrates that the parameters of a cognitive task can influence strategic behavior (also see Touron & Hertzog, 2004a). Future research endeavors need to take into consideration both participant and task factors when assessing age differences in psychological task performance, especially when acquired skill relies upon memory use. As we have shown, a relatively small task alteration, such as using a stringent prelearning criterion, can have a major effect on older adults' task performance, eliminating age-related retrieval reluctance on the part our older adult sample. Investigations of the degree of support required for older adults to behave similarly to their younger counterparts may be important for understanding how to design compensatory interventions that aid older adults' effective cognitive functioning (see Dunlosky, Bailey, & Hertzog, 2011), including those that attempt to overcome avoidable dysfunction due to low levels of memory control and memory self-efficacy beliefs (e.g., West, Dark-Freudeman, & Bagwell, 2009).

Acknowledgments

This research was supported by a grant R01 AG024485 from National Institute on Aging, one of the National Institutes of Health. We would like to extend thanks to the following personnel for their assistance with subject recruitment and data collection: Teri Boutot, Bethany Geist, Renu Kumar, Devaki Kumarhia, Stephanie LaForge, Stacy Lockler, Colin Malone, Melissa McDonald, and Alisha Monteiro. For more information on our research program, consult http://psychology.gatech.edu/CHertzog.

Notes

1 The term incidental indicates here that associative learning is generally thought to not be an explicit goal of the task participant. Although intentional memorization is a possible strategy to maximize rapid responses in memory-based skill acquisition tasks, learning new associations is

neither explicitly instructed nor expressed as the goal of the task. Individuals can perform accurately (but not efficiently) in such tasks without learning the new associations.

2 Technically, the error structure specified for the 2 × 15 within-subjects factorial part of the design was the Kronecker product of an unrestricted 2 × 2 Match error matrix with a 15 × 15 unrestricted Block error matrix (i.e., specified asUN@UN in SAS PROC MIXED; see Littell et al., 2006).

3 A reviewer questioned the reason for above-chance self-reported retrieval use during Block 1 for persons who had not prelearned the items, especially for older adults. Given that items are presented twice within a block, associative learning (and retrieval-based responding) is possible during the first block. However, one would not expect greater retrieval use by older adults in Block 1. Retrieval self-reports have been shown to be valid, on the whole (Touron, Hertzog, & Franks, 2011), but are subject to measurement error. Given that this pattern was not observed in Experiment 2, we regard it as a chance finding.

4 Touron, Frank, and Hertzog (2011) demonstrated with an eyetracking study that older and younger adults' self-reported retrieval trials appeared to be generally valid, given far fewer glances to the lookup table on reported retrieval trials. However, older adults had a slightly higher percentage of trials that appeared to involve scanning of the lookup table when retrieval was reported. These trials may be predominantly manifested early in practice.

5 Due to the similarity of findings to those of Experiment 1 (specifically, a lack of an effect of Prelearning Condition on response accuracy), accuracy data is not reported for Experiment 2.

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