Accuracy and Speed Feedback: Global and Local Effects on Strategy Use

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Abstract:

Background/Study Context: Skill acquisition often involves a shift from an effortful algorithm-based strategy to more fluent memory-based performance. Older adults' slower strategy transitions can be ascribed to both slowed learning and metacognitive factors. Experimenters often provide feedback on response accuracy; this emphasis may either inadvertently reinforce older adults' conservatism or might highlight that retrieval is generally quite accurate. Response time (RT) feedback can lead to more rapid shift to retrieval (Hertzog, Touron, & Hines, 2007, *Psychology and Aging*, *22*, 607–624).

Methods: This study parametrically varied trial-by-trial feedback to examine whether strategy shifts in the noun-pair task in younger (M = 19) and older (M = 67) adults were influenced by type of performance feedback: none, trial accuracy, trial RT, or both accuracy and RT.

Results: Older adults who received accuracy feedback retrieved more often, particularly on difficult rearranged trials, and participants who receive speed feedback performed the scanning strategy more quickly. Age differences were also obtained in local (trial-level) reactivity to task performance, but these were not affected by feedback.

Conclusions: Accuracy and speed feedback had distinct global (general) influences on task strategies and performance. In particular, it appears that the standard practice of providing trial-by-trial accuracy feedback might facilitate older adults' use of retrieval strategies in skill acquisition tasks.

Keywords: Psychology | Older adults | Skill acquisition | Performance feedback

Article:

The current study examines the influence of feedback on performance in strategic skill acquisition tasks. Learning new tasks often involves initially using a deliberate approach that involves controlled attention and considerable effort (such as mental calculation), but with practice transitioning toward a more fluent approach (such as direct retrieval of a mathematical solution; Logan, 1988; Rickard, 1997). Strategy transitions may be influenced by the mental model a person has of the task, including awareness and understanding of available strategies (Johnson-Laird, 2010; Hertzog, Touron, & Hines, 2007). Participants with a mental model that retrieval enhances response speed without adversely affecting accuracy are more likely to transition to retrieval. Monetary incentives to respond faster also encourage individuals to shift to retrieval (see Touron, Swaim, & Hertzog,2007; Touron & Hertzog, 2009).

When skill acquisition involves a qualitative shift in processing strategies, particularly use of a retrieval strategy, older adults typically shift strategies more slowly than younger adults. In part this delayed strategy shift can be accounted for by metacognitive influences (e.g., Hertzog & Touron, 2013), as detailed further below. Certainly, older adults are often more reluctant to rely on memory retrieval (Frank, Touron, & Hertzog, 2013; Hines, Hertzog, & Touron, 2012) and seem generally to be more cautious about making risky decisions in many cognitive tasks (e.g., Botwinick, 1984). Older adults often have more conservative speed-accuracy response biases in response-time tasks (Hertzog, Vernon, & Rypma, 1993; Strayer & Kramer, 1994; Ratcliff, Thapar, & McKoon, 2011), and also tend to construct poorer mental models of strategic behaviors in skill acquisition tasks, manifesting less appreciation of the relative costs and benefits of the available strategies (Frank et al., 2013; Hertzog et al., 2007).

Impact of Feedback on Performance

Age differences in the quality of task appraisal and strategic behavior can be remedied. Both young and older adults have been shown to flexibly adjust their speed-accuracy tradeoff with instruction (Strayer & Kramer, 1994). Older adults are also more likely to shift to retrieval-based strategies when they receive personal feedback on the aggregate speed with which they perform each of the available strategies (Hertzog et al., 2007). One possible explanation of these experimental effects is that the associated manipulations increase accurate awareness of the costs and benefits of different strategies. In the case of tasks affording a memory retrieval shift, the manipulations may reveal to older adults the efficiency of memory retrieval and the low risk of relying upon it.

These studies suggest that performance feedback may be critical to the development of an accurate mental model of strategy shift tasks. Indeed, it has been demonstrated that feedback benefits performance in various task domains. In a study of middle school students’ vocabulary learning, feedback on performance accuracy was shown to aid learning by adjusting errant responses (Metcalfe & Kornell, 2007). In such learning situations, providing the correct response after an error seems to be a particularly helpful type of feedback (Pashler, Cepeda, Wixted, & Rohrer, 2005); feedback makes little difference for items correctly answered. In simple data entry tasks, providing performance feedback leads to improvement in accuracy over training (when declines are seen otherwise), primarily by increasing motivation and alleviating boredom (Kole, Healy, & Bourne, 2008).

However, previous research does not show universal boosts to learning with feedback. Critically, feedback may not improve long-term retention even when it does hasten initial learning (Anderson, Corbett, Keodinger, & Pelletier, 1995). In addition, feedback has been shown to impair rather than facilitate the learning of motor skills (Bjork, 1999; Schmidt & Bjork, 1992). Feedback can sometimes be unnecessary and even costly; a study by Hays, Kornell, and Bjork (2010) found that learners who skipped offered feedback sometimes performed more accurately while also saving time. Concerning age differences in learning, Starns and Ratcliff (2010) demonstrated that instructions with feedback allowed younger adults but not older adults to optimize speed-accuracy criteria in a two-choice decision task.

An interesting fact about existing skill acquisition tasks is that the standard practice is to provide trial-by-trial feedback about accuracy to discourage fast, errorful response modes. In some studies, the goal of equating older and younger adults in speed-accuracy criteria has led to extensive accuracy feedback with instructions to maintain error rates at a constant value, such as 95% accuracy in each test block (Touron & Hertzog, 2004; Touron, Hoyer, & Cerella, 2001). In general, item-level feedback about accuracy, though sensible as a means of maximizing the number of correct trials for response time (RT) analysis, could unwittingly contribute to age differences in delayed strategy shift. If older adults are error-averse, accuracy feedback after an error on a retrieval trial may make them more reluctant to shift to a strategy that risks errors early in practice. On the other hand, accuracy feedback can indicate successful retrieval use, which might increase older adults' confidence in their use of memory strategies and increase their use of retrieval. One goal of the present study was to evaluate whether providing trial-by-trial error feedback would particularly influence older adults' shift to the memory retrieval strategy.

Most studies in the literature have concentrated on feedback regarding performance accuracy. Feedback can also be provided regarding the speed of participants' responses, but little is currently known about how speed feedback impacts performance. The amount of time taken to respond to a memory test (i.e., retrieval fluency) relates to memory performance and downstream metacognitive judgments such as response confidence and judgments of learning for a later study opportunity with the same information (Hines, Touron, & Hertzog, 2009; Hines, Hertzog, & Touron, 2013). Because older adults less accurately estimate response times in cognitive tasks (Craik & Hay, 1999), the provision of feedback on performance speed may be more critical to older adults' effective incorporation and use of fluency as a metacognitive cue.

Given that age differences in RT are influenced by older adults' conservative speed-accuracy criteria, it is also plausible that providing trial-by-trial feedback would improve older adults' RT in a skill acquisition task, either by encouraging more liberal response criteria after successful trial discriminations or by promoting use of the more efficient retrieval strategy.

Importantly, older adults have been shown to hasten shift from a slower toward a faster performance strategy when provided with response speed feedback aggregated over a block of trials for each strategy (Hertzog et al., 2007). However, performance feedback is more typically provided on the trial-level than aggregated over block and for each available strategy. It is at present unknown whether older adults may have greater difficulty integrating trial-level speed or accuracy feedback into a coherent mental task model of available task strategies.

Mechanisms for Feedback Effects in Skill Acquisition Tasks

The distinction between aggregate and trial-level feedback highlights the important question of how and whether performance feedback is used by learners to improve task performance. Presumably, initial task instructions encourage people to form a mental model of the task that includes available performance strategies and their costs and benefits (Lemaire, 2010). An optimal mental task model should also consider the relative importance of accuracy and speed for the task, and how available strategies fare in terms of these priorities. According to metacognitive theory (e.g., Nelson, 1996), monitoring performance leads to adaptive changes in strategies when needed, with adaptation based on evaluations of performance and discrepancies between performance levels and performance goals (e.g., Dunlosky & Hertzog, 1998). In this sense, adaptation requires that participants alter their initial mental task model while performing the task. Without feedback, any adjustment of the mental model would require self-initiated and accurate monitoring of task performance (Nelson & Narens, 1990). For example, monitoring retrieval products during recall tests is needed to discriminate correct candidates from intrusion errors (Koriat & Goldsmith, 1996). However, when veridical performance feedback is provided, learners are not constrained by the accuracy of performance monitoring.

Presumably, providing both accuracy and speed feedback has two benefits. First, it enables accurate adjustment of mental models regarding speed and accuracy consequences of different strategies. Second, it frees controlled processing resources that can be devoted to aspects of ongoing metacognitive control, such as selection of particular items for study, evaluation of performance strategies, or adjustment of speed-accuracy response criteria. This reduction in monitoring requirements should particularly benefit older adults who on average probably have fewer cognitive resources to spare (e.g., Bopp & Verhaeghen, 2005).

Hertzog and Touron (2011) investigated monitoring of recognition memory accuracy in the context of a skill acquisition task involving shift to retrieval. Older adults were given blocks of associative recognition memory probes without performance feedback, and were asked to rate their confidence in the accuracy of recognition memory responses. Those older adults who were less accurate in memory confidence were slower to shift to the memory retrieval strategy, suggesting that their lower ability to monitor retrieval strategy benefits may have delayed their strategy shift.

Global Versus Local Influences of Feedback

Performance feedback can have both global (general) and local (trial-specific) influences on subsequent performance. In terms of global influences, participants with an accurate general sense of the costs and benefits of available strategies (based on either performance monitoring or performance feedback) might show a general tendency to choose the more optimal strategy. Stable individual differences in variables such as retrieval monitoring, speed-accuracy response criteria, or feeling-of-knowing (Hertzog & Touron, 2011) may also have global effects on the likelihood of switching to a more effective strategy. Furthermore, performance feedback should on average be most beneficial to individuals who are globally less accurate in performance monitoring.

In terms of local influences, participants who are actively monitoring performance (or who receive performance feedback) might show a tendency to switch strategies following a trial that is slow or errant, while persevering with a strategy that just generated a fast, correct response. Such effects would be akin to the effects of response monitoring on behavioral adjustments such as posterror slowing (see Dulith et al., 2012). Indeed, Smith and Brewer (1995) demonstrated that both younger and older adults are responsive to local performance, increasing their response speed following incorrect responses (despite receiving no error feedback). Older adults' regulation was less refined, however, with greater and more extended slowing following errors.

It might seem that providing feedback obviates performance monitoring and therefore equates individuals and age groups in influences of knowing about performance levels for cognitive control. However, individuals with accurate monitoring or actual feedback do not necessarily use that information to achieve effective control (Dunlosky & Metcalfe, 2009; Mazzoni et al, 1995). In particular, older and younger adults might not use feedback in equivalent ways or to the same degree. Older adults manifest declines in metacognitive control in some studies (Dunlosky & Connor, 1997; Murphy, Schmitt, Caruso, & Sanders, 1987) even though they often manifest intact monitoring of learning and performance (Hertzog & Dunlosky, 2011). Furthermore, work on strategy knowledge updating suggests that older adults may not accurately infer the aggregate benefits of an effective strategy, even when their item-level monitoring of performance outcomes is highly accurate (Price, Hertzog, & Dunlosky, 2008). Aggregation of trial-level feedback may be more difficult or less successful for older adults (e.g., Bieman-Copland & Charness,1994; Price et al., 2008), given the demands that such processing makes on resources such as working memory.

Goals and Hypotheses

The current study separately examines the influences of speed and accuracy feedback on strategy choice in the noun-pair lookup (NP) task. In this task, centrally presented noun-pairs are verified as matching or not matching in a table at the top of the screen. Participants must first use a visual search algorithm but typically shift to a memory retrieval strategy with repetition of the noun-pairs, since the pairings in the table do not change. For both young and older adults, the memory retrieval strategy is much faster compared with the algorithm, and retrieval is also quite accurate after around forty repetitions per pair (Touron & Hertzog, 2004). Previous research has confirmed that age differences in strategy shift for the NP task are related to both slowed learning and a metacognitive aversion to retrieval choice (Touron & Hertzog, 2004; Touron et al., 2007; Frank et al., 2013).

We examine the effects of speed and accuracy feedback on both global and local indices of strategy choice for both young and older adults. If participants understand how strategies differ in terms of speed and accuracy, we should find a global increase in retrieval strategy use over training. In the current study, we are particularly interested in whether feedback influences this understanding of strategy differences, and whether there are age differences in such feedback use. We compare strategy use for young and older adults in between-subjects conditions that varied performance feedback following each trial: no feedback, accuracy feedback, speed feedback, or both accuracy and speed feedback.

At the global level, we expect that in an absence of either accuracy or RT feedback, older adults' strategy shift might be delayed because of greater uncertainty about performance accuracy and speed, especially when the memory retrieval strategy is used. These age differences should be reduced when item-level performance feedback is provided. Specifically, then, we anticipate (1) age differences in retrieval strategy use and (2) more retrieval strategy use when feedback is provided, with (3) a larger feedback-related increase in retrieval use for older participants.

We also examine more local reactivity of performance feedback on strategy use. We expect that participants will be more likely to retrieve following an accurate retrieval and following a fast retrieval, and that these tendencies might be amplified when feedback is provided. Given that performance in table scanning is not diagnostic regarding one's ability to shift to the retrieval strategy, we do not examine the local response to these trials. Thus, to isolate local influences, we examine strategy use following retrieval trials, comparing previous trial performance in terms of accuracy and speed in addition to the variables of age and feedback condition. We are particularly interested in whether retrieval strategy choice will be inhibited after retrieval errors, especially when accuracy feedback is provided. Specifically, then, we anticipate that (1) participants will retrieve more following accurate and fast retrieval; (2) the distinction between performance accuracy and speed will be larger for those with feedback; and (3) young adults will be able to differentiate performance without feedback, whereas feedback will be more necessary for older adults to make these distinctions.

METHODS

Design

The experiment was a 2 (age: young, old) × 2 (accuracy feedback: provided,L not provided) × 2 (speed feedback: provided, not provided) × 23 (training blocks: 1–23) mixed design, with age and feedback conditions as between-subjects independent variables and training block as the within-subjects independent variable.

Participants

Younger adult participants were undergraduates from University of North Carolina Greensboro (UNCG) who received course credit for their participation. Older adults were recruited from the nearby community and were compensated with a modest honorarium (approximately $10 per hour) for their participation. One hundred younger adults and 100 older adults were randomly assigned in equal numbers to the four between-subjects experimental conditions noted above. All participants were prescreened for self-reports of basic health issues that could impede participation, and were required to have good corrected visual acuity (20/50 or better). Due to participant noncompliance, computer errors, or scheduling problems, data for five younger adults and six older adults were incomplete or discarded. Participants also completed a brief battery of cognitive abilities. Group characteristics differed in expected directions by age, and are reported in Table 1.

Table 1. Means (and standard errors) of participant characteristics

Measure	**Yng_{none}**	**Yng_{acc}**	**Yng_{rt}**	**Yng_{both}**	**Old_{none}**	**Old_{acc}**	**Old_{rt}**	**Old_{both}**
Age	19.0 (.48)	20.1 (.46)	19.1 (.50)	19.2 (.47)	67.0 (.48)	66.3 (.47)	66.8 (.48)	67.5 (.47)
Education[a]	12.7 (.28)	13.4 (.27)	12.6 (.29)	12.9 (.28)	15.1 (.29)	15.0 (.28)	16.1 (.28)	16.0 (.28)
Medications[a]	1.0 (.24)	1.0 (.23)	0.5 (.24)	0.7 (.23)	2.7 (.24)	2.8 (.23)	3.4 (.24)	2.5 (.23)
Vocabulary[a]	27.8 (.51)	28.2 (.49)	30.0 (.52)	28.2 (.50)	34.0 (.52)	33.3 (.50)	33.8 (.52)	34.1 (.50)
Digit Symbol[a,b]	63.7 (1.6)	62.8 (1.6)	58.1 (1.7)	61.7 (1.6)	45.5 (1.7)	47.3 (1.6)	50.9 (1.7)	45.1 (1.6)
Digit Symbol Memory[a]	7.8 (.28)	8.0 (.27)	7.8 (.29)	8.0 (.27)	5.9 (.28)	5.3 (.28)	5.9 (.28)	5.0 (.28)

Note. Education = number of years of education completed; Medications = self-reported number of daily medications taken; Vocabulary = number correct out of 40 on the Shipley Vocabulary Test (Zachary, 1986); Digit Symbol = WAIS Digit-Symbol subtest (Wechsler, 1981); Digit Symbol Memory = symbol recall memory following the WAIS Digit-Symbol subtest (Wechsler, 1981). Conditions: none = no feedback; acc = accuracy feedback only; rt = speed feedback only; and both = both accuracy and speed feedback. [a]Age comparison $p < .01$. [b]Age × Condition interaction $p < .01$.

Materials and Procedures

A Visual Basic 6.0 program controlled stimulus presentations and response recordings. Stimuli were presented in 15-point Arial font on a 15-in.(38.1-cm) LCD *(*liquid-crystal display) monitor with a resolution of 1024 × 768. Seating and monitors were adjusted to a height and distance that optimized each participant's viewing and comfort.

The stimulus set contained 12 semantically unrelated concrete noun-pairs ranging in length from 3 to 5 letters (e.g., TABLE–APPLE), taken from Hertzog, Kidder, Powell-Moman, and Dunlosky (2002). All noun-pairs were presented in a lookup table at the top of the screen for each standard trial. Pairings in the table were consistent, but location varied randomly by trial. A centrally presented target pair was matched (i.e., identical) to one pair in the lookup table for a random half of the trials, and unmatched (i.e., rearranged) trials paired a left-hand word from one pair with a randomly selected right-hand word from a different pair. Each block of 24 trials included one matched and one unmatched trial per noun-pair.

All participants first received general task instructions and practice via computer. A 500-ms fixation warning ("+") preceded each noun-pair stimulus presentation. Responses were first followed by strategy probes to enable fine-grained evaluation of the strategy shift. Strategy probes required participants to report via keypress whether they used table scanning, memory, or another strategy (such as guessing) to complete the previous trial. Previous research has demonstrated that responding to strategy probes does not alter young or older adults' performance in skill acquisition tasks (see Experiment 1 of Touron, Hertzog, & Cerella, 2004), and has validated strategy probe self-reports by comparing response time distributions as well as patterns of eye movements (Touron, Hertzog, & Frank, 2011). In the condition with neither accuracy nor speed feedback, strategy probes were followed only by a blank intertrial interval and fixation for the subsequent trial. In the conditions with feedback, strategy probes were followed by 1500 ms trial-level feedback on performance accuracy and/or speed. Speed was indicated by RT in seconds (precision to two decimal places).

After the general task, a comprehensive mental model survey was completed. Most germane to the current study are the following questions. Participants judged how often one should use the scanning strategy compared with the retrieval strategy (on a 0 to 100 scale, with 0 marked "always use table scanning, 50 marked "equally use scanning and memory retrieval," and 100 marked "always use memory retrieval") if (a) the person's goal were to be as *accurate* as possible, and if (b) the person's goal were to be as *fast* as possible.

RESULTS

We examined strategy use and performance speed as dependent variables and expected these to vary by age and feedback condition with greater feedback effects for older adults. Unless otherwise noted, we used analysis of variance (ANOVA) to compare task performance by age (2: young versus old) and feedback condition (4: no feedback, accuracy feedback, speed feedback, or both accuracy and speed feedback). For local effects, we considered how performance was impacted by accuracy and speed on the previous trial, again expecting larger feedback effects for older adults. The alpha level was set at $p < .05$, and we report Tukey adjustment for multiple comparisons where appropriate. Reported effect sizes scale mean differences in *SD* units to aid interpretation of results, with $d > .5$ considered a medium effect and $d > .8$ considered a large effect (Cohen, 1988). The consideration of effect size is particularly critical for those analyses involving multiple planned and exploratory focused comparisons.

Global Feedback Effects

We evaluated global effects of feedback on two critical variables, retrieval use and RT. Feedback was not expected to substantially influence noun-pair task accuracy because it is generally high in all conditions without any feedback. In the current study, errors occurred on 6.4% of trials for young adults ($SE = 0.28$) and 3.9% of trials for older adults ($SE = 0.36$), varying by age, $F(1, 142) = 13.64$, $p < .001$, $d = 0.54$, and strategy ($M_{scan} = 3.3$, $SE_{scan} = 0.35$; $M_{ret} = 5.9$, $SE_{ret} = 0.42$, $F(1, 141) = 38.61$, $p < .001$, $d = 0.53$) but not by trial match, $F < 1$.

Influences on Retrieval Use

Our first question was whether strategy use would vary as a function of providing accuracy and speed feedback, and whether any such effects would vary by age. Table 2 contains distributions of retrieval strategy use as percentages of participants and stimulus items. Consistent with previous research, the distributions demonstrate larger individual differences (Rogers, Hertzog, & Fisk, 2000; Touron & Hertzog, 2004) in strategy use among older adults compared with young adults.

Table 2. Percentage of participants and items with reported retrieval use levels, by age, condition, and trial match

	$\mathbf{Yng_{none}}$	$\mathbf{Yng_{acc}}$	$\mathbf{Yng_{rt}}$	$\mathbf{Yng_{both}}$	$\mathbf{Old_{none}}$	$\mathbf{Old_{acc}}$	$\mathbf{Old_{rt}}$	$\mathbf{Old_{both}}$
% Participants, intact								
0–33% ret	0	0	0	0	17.6	5.2	6.3	5.9
34–66% ret	0	0	5	4.5	29.4	10.5	25	23.5
67–100% ret	100	100	95	95.5	52.9	84.2	68.8	70.6
% Participants, rearranged								
0–33% ret	0	0	0	4.5	35.3	0	18.8	5.9

34–66% ret	11.8	0	10	4.5	17.6	36.8	56.3	41.2
67–100% ret	88.2	100	90	90.9	47.1	63.2	25	52.9
% Items, intact								
0–33% ret	0	0	0	0	0	0	0	0
34–66% ret	0	0	0	0	0	8.3	8.3	0
67–100% ret	100	100	100	100	100	91.7	91.7	100
% Items, rearranged								
0–33% ret	0	0	0	0	0	0	0	0
34–66% ret	0	0	0	0	0	16.7	83.3	0
67–100% ret	100	100	100	100	100	83.3	16.7	100

Note. Conditions: none = no feedback; acc = accuracy feedback only; rt = speed feedback only; and both = both accuracy and speed feedback. % ret = reported percentage of retrieval use.

Aggregate data are shown in Figure 1. As expected, young adults retrieved more often compared with old, $F(1, 149) = 62.09$, $p < .001$, $d = 1.22$. Feedback condition reliably influenced retrieval use overall, $F(3, 149) = 3.27$, $p = .02$; focused comparisons follow. The source of the feedback effect is as follows. Compared with the group with no feedback, participants in the condition with accuracy feedback used the retrieval strategy more often, $p = .02$, adjusted $p = .09$, $d = 0.47$, whereas the other feedback conditions did not show a reliable difference in retrieval use compared with the no feedback condition, *p*s > .28, adjusted *p*s > .70.

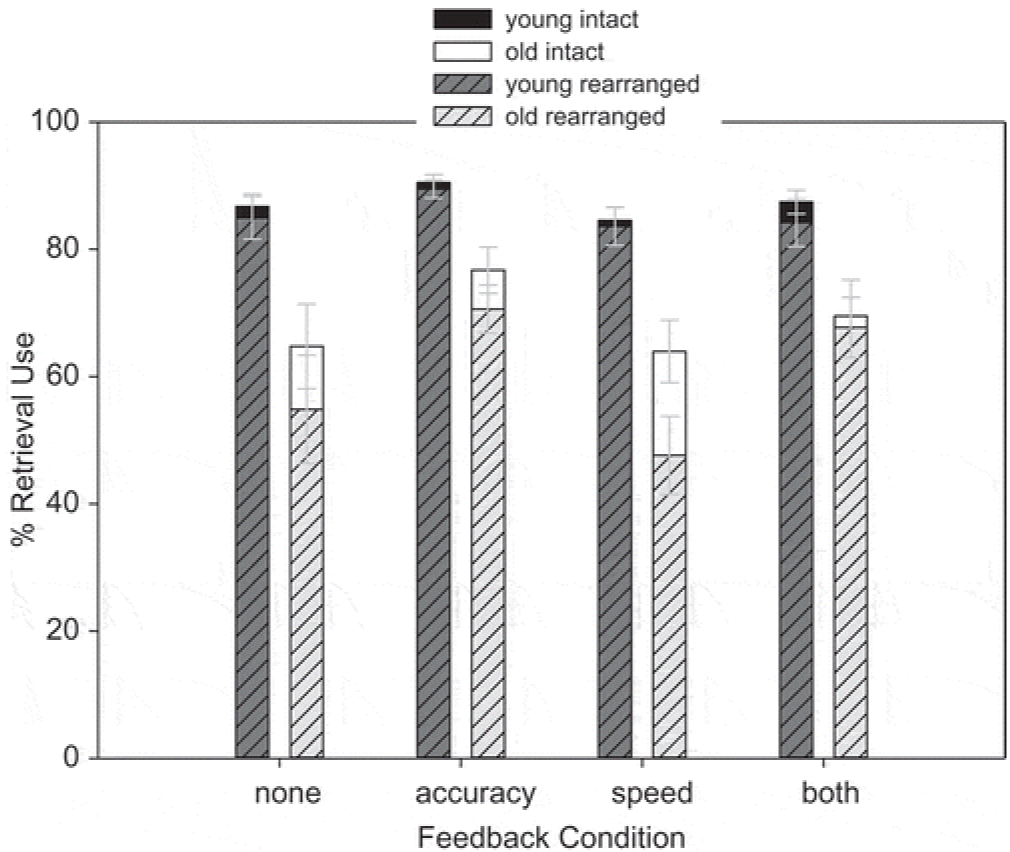

Figure 1. Percent retrieval use (with SE bars) is presented by age, feedback condition, and trial match.

Feedback condition did not interact with age, $F(3, 149) = 1.01$, $p = .39$. Given our a priori expectations of age differences and the reliable effect of accuracy feedback, we nonetheless conducted focused planned comparisons for the accuracy feedback effect in young and older adults. The effect of accuracy feedback approached reliability for older ($p = .01$, adjusted $p = .09$, $d = 0.58$) but not younger ($p = .43$, adjusted $p = .99$, $d = 0.48$) adults. Judging from the effect sizes, it appears that both groups' retrieval use tended to increase with accuracy feedback, indicating no major age difference in feedback effects. Speed feedback did not appear to have a global influence on strategy choice.

We also compared the effects of age and condition on retrieval strategy use while considering the influence of trial match (intact pair or rearranged pair). Previous work has suggested that older adults have particular difficulty with rearranged pairs in standard associative recognition memory tasks (Old & Naveh-Benjamin, 2008). In the noun-pair task, older adults are specifically less likely to retrieve when presented with rearranged pairs (Hertzog & Touron, 2011). As predicted, the main effect of match was reliable, $F(1, 142) = 25.01$, $p < .01$, $d = 0.32$, with lower retrieval use for rearranged compared with intact pairs. This difference interacted with age, *F*(1,

142) = 12.03, $p < .01$, with older adults showing differentially lower retrieval use on trials with rearranged pairs. The interaction of match and condition just missed statistical significance, $F(3, 142) = 2.52$, $p = .06$, but the three-way interaction of match, age, and condition was reliable, $F(3, 142) = 3.73$, $p < .05$.

The source of this interaction is as follows. For young adults, there were no feedback condition differences in retrieval use for intact items (*p*s > .46, adjusted *p*s > .92) or rearranged items (*p*s > .47, adjusted *p*s > .97). In contrast, focused comparisons revealed different feedback patterns for older adults depending on trial match. When older adults responded to intact items, retrieval use increased compared with no feedback more for participants in the condition with accuracy feedback ($p = .03$, adjusted $p = .33$, $d = 0.53$), relative to no differences in retrieval use between the no feedback condition and the condition with both accuracy and speed feedback ($p = .38$, adjusted $p > .99$) or those in the condition with speed feedback only ($p = .56$, adjusted $p > .98$). This pattern of higher retrieval use by older adults with accuracy feedback was magnified for rearranged items. Retrieval use increased compared with no feedback more for older participants in the conditions with accuracy feedback ($p = .02$, adjusted $p = .23$, $d = 0.57$) with a smaller increase compared with no feedback for participants in the condition with both accuracy and speed feedback ($p = .055$, adjusted $p = .53$, $d = 0.45$), but no difference in retrieval use for rearranged items in the condition with speed feedback only ($p = .29$, adjusted $p > .96$).

In summary, feedback appears to have primarily influenced age differences in the NP task by increasing older adults' retrieval use on rearranged items when accuracy feedback was provided. Speed feedback did not substantially influence retrieval use by either age group. We consider the potential implications of these outcomes in the Discussion section.

Influences on Response Times

We were also interested in whether accuracy or speed feedback might influence response speed and whether this influence would vary by age. For all analyses of RT, we examined participant medians to protect against the influence of outliers; aggregate data present groups means of individual medians. Data are shown in Figure 2. In addition to the primary model, we compared ANOVAs including the match variable, both with and without the strategy variable (2: retrieval, scanning) in order to maximize power. The main effect of match was not significant in any of these comparisons (*p*s >.06, $d = 0.18$), nor were any of the interactions associated with match (*p*s > .1), so we do not consider match effects further. As expected, young adults responded more quickly compared with old, $F(1, 149) = 267.98$, $p < .001$, $d = 1.12$. Feedback condition reliably influenced RT overall, $F(3, 299) = 22.75$,$p < .001$; focused comparisons follow. The group with no feedback and the group with accuracy feedback did not differ, $p = .43$, adjusted $p = .86$. In contrast, the group with speed feedback and both accuracy and speed feedback each responded more quickly compared with either group without speed feedback (*p*s < .001, adjusted *p*s < .001, *d*s > .39) but did not reliably differ ($p > .07$, adjusted $p = .27$). As such, the provision of speed feedback was most consequential to response speed. The interaction between feedback condition and age was not reliable, $F(3, 299) = 1.52$, $p = .21$.

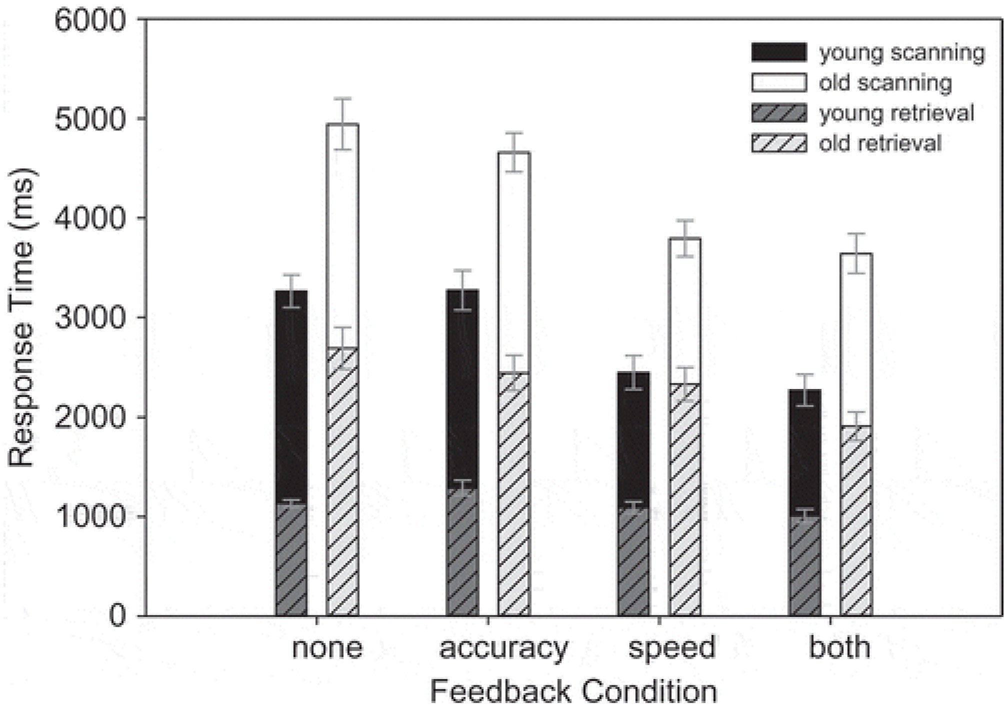

Figure 2. Response time (with *SE* bars) is presented by age, feedback condition, and strategy used.

The strategy effect confirmed that retrieval was faster than scanning, $F(1, 142) = 750.58$, $p < .001$, $d = 1.72$, and this strategy difference was similar for young and older adults, $F(1, 142) = 3.10$, $p = .08$. The strategy difference interacted with feedback condition, $F(1, 142) = 9.28$, $p < .001$. Speed feedback resulted in dramatically faster RTs for scanning trials ($p < .01$, adjusted $p < .01$, $d = 0.96$), relative to improvements in retrieval RT ($p = .23$, adjusted $p = .93$, $d = 0.42$), whereas accuracy feedback did not improve RTs in either strategy (*p*s > .39, adjusted *p*s > .99). The three-way interaction of age, condition, and strategy was not significant, $F(3, 142) < 1$. In summary, the provision of speed feedback dramatically improved noun-pair RTs for both age groups when the scanning strategy was used. Accuracy feedback did not affect noun-pair RTs, contrary to a hypothesis that conservative speed-accuracy criteria for older adults would be differentially altered by performance feedback. These results indicate that the biggest effect on age differences in overall RT is strategy choice (given that retrieval generates faster RTs), and that speed feedback does not materially change age differences in RT with either strategy.

Local Effects of Feedback on Strategy Use

To consider how trial-level accuracy and speed feedback might dynamically influence performance on a trial-to-trial basis, we evaluated whether feedback on a given trial affects subsequent task behavior on the next trial. As previously noted, we confined these analyses to examining trials subsequent to retrieval trials, since scanning performance is not diagnostic of retrieval ability.

Accuracy Feedback

We expected that participants should retrieve less after a retrieval error, compared with after a correct retrieval. If older adults' accuracy monitoring for retrieval trials is imperfect (e.g., Hertzog & Touron, 2011), its effects on retrieval use might be mitigated by providing feedback on trial accuracy. We used ANOVA to compare percent retrieval reports by age (2: young versus old), feedback condition (2: no feedback, accuracy feedback), and accuracy on the previous trial (2: correct, error). To focus on the particular impact of retrieval success versus failure, analysis was confined to trials following reported retrievals. Data are shown in Figure 3.

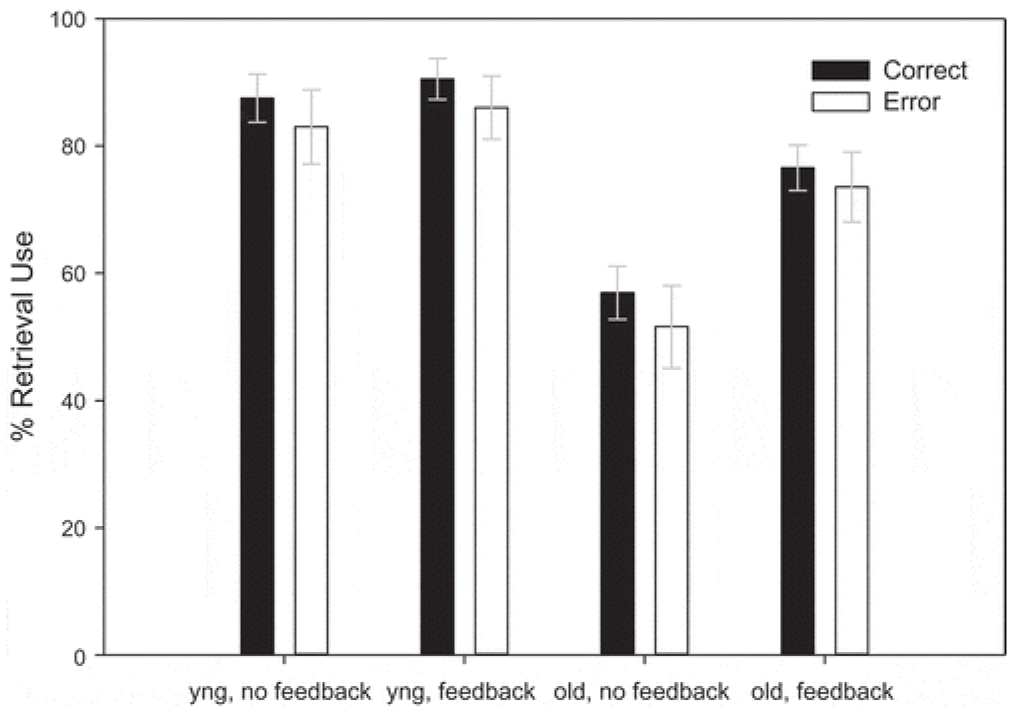

Figure 3. Percent retrieval use (with SE bars) is presented by age, feedback condition, and last trial accuracy.

The age difference was again reliable, with young adults more likely to retrieve following a retrieval trial compared with older adults, $F(1, 65) = 26.59$, $p < .001$, $d = 1.12$. The condition difference was also again reliable, with participants in the condition with accuracy feedback more likely to retrieve following a retrieval trial compared with those in the condition with no feedback, $F(1, 65) = 7.71$, $p < .01$, $d = 0.44$. The age by condition interaction was reliable in this case, with a greater accuracy feedback effect for older adults compared with young adults, $F(1, 65) = 4.30$, $p = .04$. These outcomes underscore the global effects of these variables already reported.

Most germane to the question of local effects is the effect of previous retrieval accuracy on retrieval use. Participants were more likely to retrieve following a correct retrieval compared with an error, $F(1, 65) = 3.89$, $p < .05$, $d = 0.22$. That is, errors when using retrieval apparently led to a shift to the scanning strategy on the next NP trial. However, this effect did not vary by age or feedback condition, all interaction Fs < 1. Thus, performance accuracy influenced subsequent retrieval reliance by both young and older adults, but this did not seem to be affected by the provision of explicit feedback.

Speed Feedback

We expected that participants should retrieve less after a slow retrieval, compared with after a fast retrieval. If response time monitoring is imperfect, this difference might be promoted by feedback on trial speed, particularly for older adults. To consider the particular impact of retrieval fluency, analysis was again confined to trials following reported retrievals. Again most germane to the present question is the effect of previous retrieval speed on retrieval use. We used SAS PROC GENMOD (SAS Institute, 2008) to perform a repeated-measures logistic regression predicting trial strategy (retrieved or scanned) based on age (2: young versus old), feedback condition (2: no feedback, speed feedback), and speed on the previous trial (centered for each individual on their mean retrieval RT), with individual participants specified in the model.

Retrieval speed for the previous trial did influence strategy choice, $\chi^2(1) = 6.55$, $p = .01$, and the interaction confirmed that this effect was larger for young adults, $\chi^2(1) = 10.29$, $p < .01$. However, no influence or interactions with the feedback condition were found (ps > .5). For purposes of illustration, Figure 4 contains data using a median split of the trial speed variable for each individual (ANOVA on these data led to the same outcomes). Retrieval speed influenced subsequent retrieval reliance, particularly for younger adults, but this did not seem to be affected by the provision of explicit feedback.

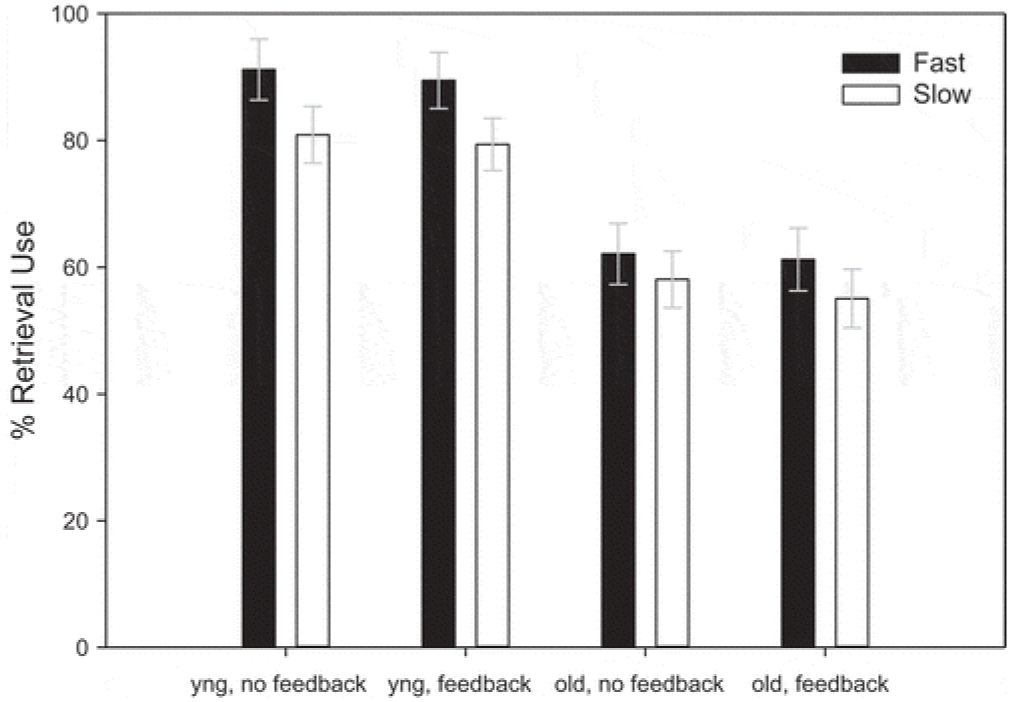

Figure 4. Percent retrieval use (with SE bars) is presented by age, feedback condition, and last trial speed.

Local Effects of Accuracy Feedback on RT

Older adults' greater tendency for posterror slowing might also be exacerbated when the previous trial was accompanied by explicit feedback about their errors. We expected that participants (particularly older adults) should respond more slowly after an error, compared with after a correct response. If accuracy monitoring is imperfect, this difference might be promoted by feedback on trial accuracy (again, particularly for older adults). We used ANOVA to compare RT by age (2: young versus old), feedback condition (2: no feedback, accuracy feedback), and accuracy on the previous trial (2: correct, error).

As expected, we obtained a reliable age difference echoing the analysis above, but no difference in RT by accuracy feedback condition or with the Age × Condition interaction (*p*s > .22). The main effect of previous trial accuracy was reliable, $F(1, 65) = 21.16$, $p < .001$, $d = 0.32$, and the interaction with age approached significance, $F(1, 65) = 3.41$, $p = .07$. The trend was consistent with previous findings, with more pronounced posterror slowing for older adults ($M_{\text{post-correct}}$ = 3206, $SE_{\text{post-correct}}$ = 121; $M_{\text{post-error}}$ = 3900, $SE_{\text{post-error}}$ = 197, $d = 0.60$) compared with young adults ($M_{\text{post-correct}}$ = 1422, $SE_{\text{post-correct}}$ = 109;$M_{\text{post-error}}$ = 1719, $SE_{\text{post-error}}$ = 178, $d = 0.44$). No interactions with feedback condition were detected (*p*s > .29). Comparisons of local effects of speed feedback on RT yielded no reliable effects.

Mental Model Effects

After the task, participants judged how often one should use the retrieval strategy if their goal was to be accurate and separately how often one should use the retrieval strategy if their goal was to be fast. For the accuracy goal question, we used ANOVA to compare these judgments by age (2: young versus old) and feedback condition (2: no feedback, accuracy feedback). The age difference was not reliable, $F < 1$, but higher retrieval preference was reported by participants who had received accuracy feedback during the task, $F(1, 74) = 7.58$, $p < .01$, $d = 0.66$. Although scanning typically generates near-perfect accuracy in the noun-pair task, feedback seems to reinforce the fact that retrieval is still quite accurate (older adults in the accuracy feedback condition scanned at 99% accuracy and retrieved at 95% accuracy). The age by condition interaction in retrieval preference was not reliable, $F(1, 74) = 3.22$, $p = .08$, but the trend and focused comparisons suggested an increase with feedback by young adults (M_{feedback} = 72.05, SE_{feedback} = 5.77; M_{none} = 43.8, SE_{none} = 6.57; $p < .01$, $d = 1.02$) but not older adults (M_{no} = 53.8,SE_{no} = 6.57; M_{feed} = 59.5, SE_{feed} = 6.21, $p = .53$, $d = 0.22$).

For the speed goal question, we used ANOVA to compare these judgments by age (2: young versus old) and feedback condition (2: no feedback, speed feedback). The age difference, $F(1, 69) = 4.48$, $p < .04$,, $d = 0.51$, indicated higher retrieval preference with a speed goal by young adults ($M = 76.0$, $SE = 5.71$) compared with older adults ($M = 59.4$, $SE = 6.02$). Higher retrieval preference for a speed goal were also given by participants who had received speed feedback during the task (M_{feedback} = 75.9,SE_{feedback} = 5.8; M_{none} = 59.6, SE_{none} = 5.93), $F(1, 69) = 3.96$, $p < .05$, $d = 0.49$. The age by condition interaction was not reliable, $F < 1$. Given that retrieval is markedly faster in the noun-pair task compared with scanning (older adults in the speed feedback condition scanned in 3.7 s and retrieved in 1.9 s), the age difference is consistent with previous findings of RT monitoring deficits by older adults. Notably, however, although both young adults' and older adults' retrieval preference adjusted after speed feedback, that feedback did not eliminate age differences in this aspect of the mental model, which may be critical for governing older adults' decisions to scan rather than retrieve on any given noun-pair trial.

DISCUSSION

Older adults show lower accuracy of confidence judgments in associative recognition memory tasks (Hines et al., 2009), and this tendency is related to their use of the retrieval strategy in the noun-pair task (Hertzog & Touron, 2011). Consequently, feedback about accuracy and speed of response both affect NP task performance in the present study, in all likelihood repairing inaccuracy in performance monitoring. Older participants who received accuracy feedback used the retrieval strategy more often than older participants not receiving accuracy feedback, particularly for rearranged items. This finding implicates deficient performance monitoring by older adults as a contributing factor to their delayed retrieval shift.

The present study also indicated that the standard practice of providing trial-level accuracy feedback in skill acquisition tasks increases retrieval use by older adults by repairing what would otherwise be deficient implicit performance monitoring for rearranged trials. Accuracy feedback may therefore counter older adults' subjective expectations that relying on memory retrieval for rearranged items will be less accurate than using an external algorithm such as visual search.

In contrast, speed feedback did not appear to have a global influence on strategy use. Given well-established age differences in response time monitoring (e.g., Craik & Hay, 1999) and the large differences in response speed between the table scanning and retrieval strategies, this finding was surprising. Hertzog et al. (2007) found that older adults were more likely to transition to a retrieval strategy in the NP task when provided with speed feedback aggregated by strategy at the end of each presentation block. It is possible that participants in the present study had difficulty aggregating feedback provided on individual NP trials into an aggregate task mental model of retrieval as a more efficient strategy relative to the visual scanning strategy. Forming an accurate mental model was probably more directly supported by providing block-level feedback in the Hertzog et al. (2007) study. Speed feedback did influence response times by leading to faster table scanning, but it did not affect retrieval speed or use.

Local (trial-by-trial) performance also influenced subsequent strategy choice, with participants retrieving more on a trial preceded by a trial with accurate and fast retrieval. The local effect of retrieval speed on strategy choice was larger for young adults compared with older adults, perhaps due to older adults' having response criteria less focused on performance speed. However, neither accuracy nor speed feedback appeared to influence these local effects. Older adults were also reactive to local performance in terms of trial speed, with more pronounced posterror slowing compared with young (e.g., Smith & Brewer, 1995). However, the finding that older adults were no more likely to scan following an errant retrieval might indicate that age differences in posterror slowing involve general performance slowing but not conservatism in strategy selection.

The consideration of local effects also informs recent findings on sequential strategy use. Lemaire and colleagues have demonstrated strategy switch costs, which reduce performance when participants switch strategies from trial to trial (Leamaire & Lecacheur, 2010; Uttenhove & Lemaire, 2012), and that these costs are greater for older compared with younger adults (Ardiale & Lemaire, 2012). Older adults are less likely to shift strategies on an item-by-item basis, perhaps waiting until they can shift collectively for the item set due to the costs associated with nonsequential strategy use (Touron, 2006). The present results indicate that strategy selection is influenced not only by the previous strategy used but also by the success of that strategy execution in terms of accuracy and speed.

Data from the mental model survey were consistent with the idea that feedback has a global impact on strategy beliefs. When presented with a goal to be accurate, participants who received accuracy feedback were more likely to endorse retrieval strategy use. When presented with a goal to be fast, young adults were generally more likely to endorse retrieval strategy use. Only older participants who received speed feedback were more likely to do so. It appears, then, that accuracy feedback improved older adults' inferences about the efficiency of the retrieval strategy. It is important to note, however, that the mental model outcomes for speed feedback were not associated with global influences of speed feedback on strategy use, where feedback was not shown to influence online retrieval choice. It therefore appears that it is chiefly accuracy feedback that changes participants' task mental models regarding the retrieval strategy, which in turn may have contributed to older adults' increased retrieval use when provided with performance feedback.

The current study measured strategy beliefs and preferences only after the task was completed. There is no reason to anticipate that strategy beliefs varied by feedback condition prior to the task. However, future research should consider whether initial task understanding differs for young and older adults. Furthermore, measuring task understanding regularly during the task may shed light on the timing of feedback effects on the task mental model and how these vary by age. It is also notable that the mental model responses did not correlate with initial or late retrieval use in the present study (ps > .13); although this may reflect inadequate power to detect correlations, it also might indicate a disjoint between strategic behavior during the task and posttask strategy beliefs. The present study indicates that accuracy feedback influences older adults' strategy selection and beliefs in the noun-pair task, but it is important to recognize that this research was largely exploratory and that future research is needed to replicate and further understand the nature of these effects.

It is likely that task understanding and strategy beliefs influence age differences in performance for various cognitive tasks. The present study utilized the noun-pair lookup task, but older adults are also retrieval avoidant in other task contexts, including novel arithmetic (Touron & Hertzog, 2009), alphabet verification (Frank et al., 2013), and reading comprehension (Rawson & Touron, 2009). More broadly, age differences in strategy selection and execution have been documented in tasks as diverse as associative learning, reasoning, and decision-making (see Lemaire, 2010, for a review). For any cognitive task that allows for multiple strategies varying in efficiency and effectiveness, individuals performing the task may weigh their perceived costs and benefits in order to select an approach, either in terms of global preference or responding to a given trial. Indeed, theoretical models of strategic behavior, such as Rieskamp's Strategy Selection Learning (SSL) theory of how expectations and reinforcement influence inferential reasoning (Rieskamp & Otto, 2006) and Siegler's Strategy Choices and Strategy Discoveries (SCAD) theory describing the development of arithmetic skill (Shrager & Siegler, 1998), typically assume that strategy choice is based on underlying task understanding and beliefs, with adaptive strategy changes guided by experience and learning based on implicit or explicit performance feedback. During task performance, explicitly provided performance feedback may support the process of strategy comparison and decisions by reducing the demands of metacognitive monitoring. When this feedback can counter potentially errant general beliefs held by individuals, such as older adults' low memory self-efficacy, feedback may more broadly influence strategic choices, as with the current increase in older adults' retrieval use with (generally positive) accuracy feedback.

However, feedback may only be supportive to the extent that it can be readily utilized. The present study did not find that trial-level speed feedback corrected older adults' RT monitoring deficits, contrary to previous work showing that aggregate strategy-level speed feedback does increase retrieval use. This outcome suggests that, for complex tasks that involve many possible strategies or for which the most appropriate strategy varies by stimulus type, performance feedback might be influential only if aggregated rather than provided on the trial level. Further experiments will be required to address when and whether trial-level speed feedback could have larger effects than the ones seen here.

In summary, the present study demonstrates that accuracy and speed feedback can have distinct global influences on age differences in strategy shift and performance during the noun-pair task. Further research is needed to further determine the parameters for which performance feedback might reduce the resource demands of metacognitive monitoring, improve the task mental model, and drive more adaptive strategy selection.

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Notes

Note. Education = number of years of education completed; Medications = self-reported number of daily medications taken; Vocabulary = number correct out of 40 on the Shipley Vocabulary Test (Zachary, 1986); Digit Symbol = WAIS Digit-Symbol subtest (Wechsler, 1981); Digit Symbol Memory = symbol recall memory following the WAIS Digit-Symbol subtest (Wechsler,1981). Conditions: none = no feedback; acc = accuracy feedback only; rt = speed feedback only; and both = both accuracy and speed feedback.

[a]Age comparison $p < .01$.

[b]Age × Condition interaction $p < .01$.

Note. Conditions: none = no feedback; acc = accuracy feedback only; rt = speed feedback only; and both = both accuracy and speed feedback. % ret = reported percentage of retrieval use.

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