

## Eye movements and strategy shift in skill acquisition: Adult age differences.

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### **Abstract:**

**Objectives.** The current article explores age differences in skill acquisition. We validated strategy self-reports, evaluated whether eye movements may be automatic as well as information seeking, and considered the contribution of eye movements to age differences in overall performance.

**Methods.** Young and older adults performed the noun-pair lookup (NP) task. With practice, pairs (e.g., IVY-BIRD) in a lookup table can be verified by memory rather than by visual search. Trials used (1) standard stimuli, (2) memory tests without the lookup table, or (3) memory tests with a table filled with uninformative placeholders.

**Results.** For standard trials, reported scanning was associated with more table gazes, relative to reported retrieval. The lookup table was occasionally fixated during reported retrieval, particularly by older adults, but the table target pair was no more likely to be gazed than other table pairs. For memory probes, older adults also gazed the lookup table when filled with placeholders, indicating that eye movements can represent attentional capture rather than information seeking.

**Discussion.** Strategy self-reports in the NP task can be considered valid measures of strategy use. However, unnecessary automatic eye movements that appear to influence older adults' NP task performance cannot be identified by strategy reports alone.

**Keywords:** eye movements | skill acquisitions | strategies | gerontology | psychology | aging

### **Article:**

Age differences in skill acquisition have been attributed to deficits in learning (Cerella, Onyper, & Hoyer, 2006) as well as to strategic behavior (Rogers, Hertzog, & Fisk, 2000; Touron & Hertzog 2004a, 2004b). Skill acquisition tasks often involve a transition from an effortful

algorithm-based strategy to a strategy that involves a fluent memory-based retrieval strategy. In such tasks, use of retrieval substantially reduces response time (RT), but at the cost of risking errors early in practice, when the strength of the newly learned associations is weak.

We have used the noun-pair learning (NP) lookup task (Ackerman & Woltz, 1994) to assess how quickly individuals switch from slow and controlled processing to fluent retrieval-based performance. Participants initially must scan a table of noun-pairs at the top of the screen to determine if one of them matches a centrally presented probe pair (i.e., a visual search strategy). When the pairings in the table remain the same across trials, participants can learn these associations and respond based on memory retrieval.

Comparison of strategy shifts during skill acquisition can be augmented by collecting strategy self-reports on each trial about whether participants used the algorithm-based strategy or memory retrieval for the previous trial. The NP task also allows for memory tests, which require judging the pair as intact without presenting the lookup table. These measures allow tracking of how item-specific associative learning leads to strategy shift (e.g., Touron, 2006). Using this approach, Touron and Hertzog (2004a, 2004b) showed that older adults are reluctant to rely on a memory retrieval strategy, despite sufficient learning to support accurate recognition memory. This retrieval reluctance contributes to age differences in NP task RT after extended practice. Manipulations such as retrieval incentives increase retrieval use and substantially reduce older adults' RT, consistent with retrieval reluctance (e.g., Touron, Swaim & Hertzog, 2007).

However, the inference of retrieval reluctance depends partly on the validity of strategy self-reports. Alternative means of gauging strategy use, such as RT distributions, require aggregation over many trials, allow only a person-level inference about modal strategic behavior, and do not permit evaluation of the temporal dynamics of strategy shift. Strategy self-reports have previously been validated using patterns of response outcomes, such as by showing that reported scanning and retrieval trials have very different RT distributions (e.g., Touron et al., 2007). In other skill acquisition tasks, reported algorithm trials also demonstrate characteristics of effortful processing, such as addend effects, which are absent in the fluent retrieval report trials (Hoyer, Cerella, & Onyper, 2003).

The current article explores age differences in eye movements during the NP task with three primary goals. Our first goal was to track eye movements during the NP task as a means of validating retrieval reports. A second goal was to address possible explanations for eye movements to the lookup table that might occur despite self-reported retrieval. A third goal was to consider eye movements, which might contribute to age differences in task performance.

We hypothesized that strategy self-reports are indeed valid indicators of strategy use. This hypothesis predicts eye movements to the lookup table on reported scanning trials but not on reported retrieval trials. Alternatively, it is possible that fixations on the table occur even when people are actually using the retrieval strategy. Such movements might occur for various reasons and might be purposeful or automatic. Saccades to the table that are unintentional and not information seeking would not invalidate retrieval strategy reports.

We also hypothesized that older adults will demonstrate inefficient eye movements, which contribute to age differences in performance. Older adults' visual search is generally effective and governed by similar mechanisms compared with young adults', although successful search is slowed with aging (e.g., Kramer, Scialfa, Peterson, & Irwin, 2001; Madden, 2007; Scialfa & Joffe, 1997). However, older adults make inefficient eye movements in novel visual search tasks compared with young adults (Becic, Boot, & Kramer, 2007) and have little awareness of reflexive eye movements (Kramer, Hahn, Irwin, & Theeuwes, 2000). Older adults can also approach visual search tasks with more conservative search criteria, which in the NP task may lead to purposeful eye movements to the lookup table despite using memory retrieval. For example, older adults engage in more verification behaviors in a version of the NP task that requires visual scanning on all trials (Mitzner, Touron, Rogers, & Hertzog, in press).

The current study examined both intentional and automatic eye movements, which might influence age differences in task performance. Older and younger adults performed the NP lookup task while eye movements were tracked. Half of the noun-pairs were prelearned to allow for the examination of more retrieval trials (see Touron & Hertzog, 2004a). We manipulated the content of the lookup table to test for attentional capture to the table when memory retrieval is used. To do so, the lookup table was manipulated to be present, absent, or filled with uninformative placeholders. Eye movements to an absent table, when participants were informed of this fact, would indicate that eye movements to the lookup table region are not strictly information seeking. Instead, they may occur due to behavioral inertia, in which actions are reflexively and perseveratively executed out of habit (e.g., Mayr & Bell, 2006). Alternatively, eye movements to a filled table, when participants know in advance that the table contains only uninformative placeholders, would indicate that eye movements to the lookup table may involve habit-based automatic attentional capture. Individuals may saccade to the filled table even though they know that it does not contain target pairs. Spieler, Mayr, and Lagrone (2006) showed that older adults perseverate in fixating previously relevant regions in the visual environment, even after being informed the information there is no longer germane. More generally, older adults have been shown to have deficits in selective attention and specifically show decreased

inhibition of attention to irrelevant stimuli (e.g., McDowd & Filion, 1992). Well-known age-related deficits in inhibition and executive control could increase the likelihood of attentional capture by the filled table ( Craik & Byrd, 1982; Hasher & Zacks, 1988; West, 1996).

To summarize, we hypothesized that strategy self-reports are valid indices of strategy use, such that eye movements to the lookup table would either not occur or would be due to attentional capture on reported retrieval trials. We further hypothesized that older adults would demonstrate more inefficient eye movements compared with young adults, which influence age differences in task performance.

## EXPERIMENT 1

### Methods

#### Design.

The between-subject independent variables included age (young vs. old) and condition (absent table vs. filled table during memory tests). Equal numbers of young and older adults were randomly assigned to each condition. The within-subject independent variables included pair type (prelearned vs. new), gaze location (probe vs. table), and task block (1–10). The dependent variables included prelearning blocks, retrieval reports, and gaze counts.

#### Participants.

Twenty young adults (aged 18–21 years,  $M = 18.8$ ) and 20 older adults (aged 59–76 years,  $M = 66.6$ ) participated. Students received extra credit, and adult participants received \$30. Participant characteristics were broadly consistent with samples of this type in the literature (see Table 1). Older adults had higher levels of education and reported taking more daily medications. All were prescreened for (1) visual acuity using the Lighthouse Near Visual Acuity test (at least 20/50 with correction required) and (2) health-related impediments, which substantially impact cognitive ability. Participants were required corrective lenses, but individuals with multifocal lenses were excluded because of possible difficulties in eye tracking.

#### **Table 1.**

## Means (and standard errors) of Participant Characteristics

Measure	Young		Old			
	Absent	Filled, Experiment 1	Filled, Experiment 2	Absent	Filled, Experiment 1	Filled, Experiment 2
Education <sup>a</sup>	12.9 (0.83)	12.5 (0.88)	12.5 (0.29)	15.7 (3.3)	16.8 (2.4)	16.7 (0.75)
Medications <sup>a</sup>	0.91 (0.30)	0.46 (0.66)	1.62 (0.35)	3.59 (2.3)	2.54 (2.1)	2.67 (0.37)
Vocabulary <sup>a</sup>	30.1 (1.23)	27.5 (0.91)	29.9 (0.92)	33.42 (0.81)	33.64 (1.02)	34.9 (1.0)
Digit symbol <sup>a</sup>	66.4 (3.51)	68.9 (2.82)		48.8 (3.52)	52.8 (1.99)	
DS memory <sup>a</sup>	7.1 (0.43)	8.5 (0.31)		4.9 (0.47)	4.4 (0.62)	

Notes: Vocabulary = number correct out of 40 on the Shipley Vocabulary Test (Zachary, 1986). Digit symbol (Note that the digit symbol task is somewhat similar to the NP lookup task, in that each involves possible transition from visual search to memory-based processing; however, several important distinctions exist such as training time and provided strategy information. Perhaps due to these differences, we generally do not see correlations between NP strategy shift and DS performance.) = WAIS Digit symbol subtest (Wechsler, 1981). Digit Symbol Memory = symbol recall memory following the WAIS Digit symbol subtest (Wechsler, 1981). The Digit symbol task was incorrectly administered in many cases for Experiment 2 so is not reported here.

<sup>a</sup> Age comparison  $p < .05$ . No comparisons of or interactions with the condition variable were significant.

### Apparatus.

A Visual Basic 6.0 program controlled presentations and recordings. Stimuli were presented in 15-point Arial font on a 15-in (38.1 cm) LCD monitor with a resolution of  $1024 \times 768$ . Participants sat so their viewing distance from the computer screen was approximately 53 cm.

An Applied Science Laboratories eye-tracker (Model H6HS with eyehead integration) recorded at a sampling rate of 120 Hz. Areas of interest (AOIs) were categorized to rectangular areas of equal size surrounding each noun-pair, with boundaries set to the midpoints between vertical and horizontal elements. Pupil diameters recorded as zero for 12, or more consecutive samples were considered blinks and excluded; samples outside the AOIs were also excluded. Fixations were defined as two consecutive eye positions within an AOI. Gazes were defined as beginning at the onset of a fixation within an AOI and ending with the offset of the last fixation within that AOI. Because we did not find any age differences in gaze durations for either the probe or table locations in this study (consistent with visual search task outcomes by Mitzner et al., in press), we will not examine gaze duration data further.

### Materials.

The stimulus set contained six 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). Figure 1 presents a standard NP task trial and a scale representing stimulus visual angles. All six noun-pairs were presented in the lookup table for each standard trial; pairings in the table were consistent, but location varied randomly by trial. Due to these features, the task initially requires visual search, but with repetition, participants may learn the pairs and respond via memory retrieval. A central pair was matched (i.e., identical) to one in the lookup table for a random half of the trials, and unmatched trials paired a left-hand word from one pair with a randomly selected right-hand word from a different pair.

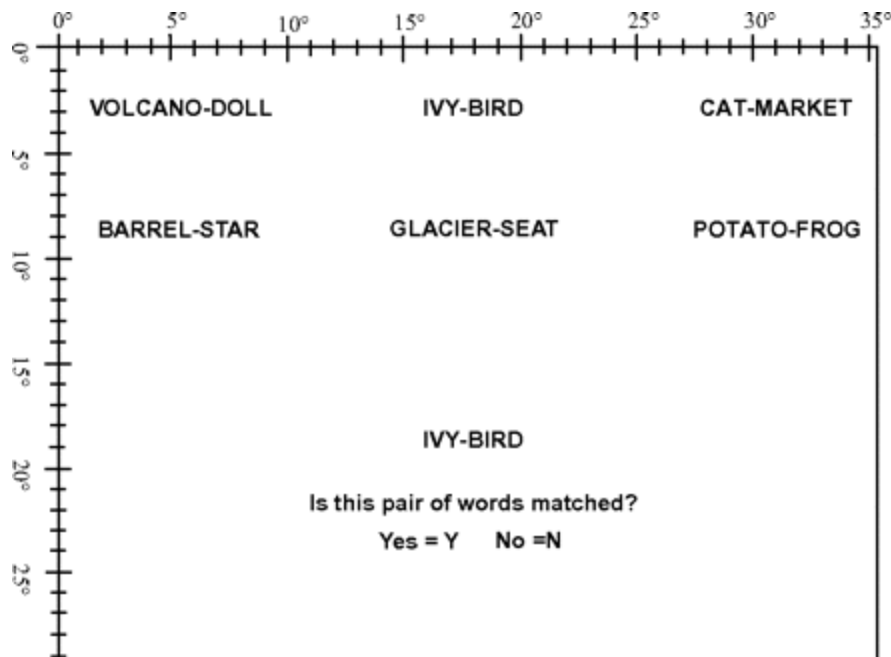


Figure 1.

Screen shot of a standard trial in the NP lookup task. The scales provide degrees of visual angle when seated at a distance of 53 cm.

Procedure.—

Task instructions followed 9-point eye tracker calibration. Participants first prelearned three pairs using a study-test procedure to a criterion of more than 90% accuracy in 12 trials. Participants then completed the NP task with six pairs (three prelearned and three new). Ten blocks each contained 18 trials, with 2 standard trials and 1 memory test per pair.

Standard trials included a central probe and the lookup table and were followed by strategy probes. For the trial response, participants pressed labeled keys to respond: “Y” if the probe was matched in the table or “N” if unmatched. Participants reported strategy use as: “S” for scanning, “M” for memory retrieval, “B” for both, or “O” for “other.” Memory tests were the same as standard trials except that the lookup table was absent in the absent condition and filled with placeholders (XXXX-XXXX) in the filled condition. A 1-s interval separated trials and presented “MEMORY” centrally before memory trials to inform participants of the upcoming trial type (i.e., that the lookup table would not be available). The stimulus disappeared immediately upon participant response. If participants responded to the trial incorrectly, the trial was followed by presenting “ERROR” centrally on the screen for 1 s. Each block was followed by a short break.

## Results

Unless otherwise noted, data were analyzed using repeated measures analyses with the general linear model. Median RTs and durations were analyzed to reduce the influence of positive skew and outliers, which occur from fast guessing or attentional lapses; we report group means of participant medians. Analyses (excepting accuracy data) included correct trials only; incorrect responses were infrequent and therefore not examined separately.

### Prelearning trials.—

The number of study-test blocks required to reach criterion (more than 90% accuracy in 12 trials) showed a marginally reliable age difference,  $F(1, 39) = 3.15$ ,  $p = .08$ ,  $d = 0.66$ , with more blocks required for older adults ( $M = 2.6$ ) versus young adults ( $M = 1.3$ ). Older adults also responded more slowly,  $F(1, 39) = 6.16$ ,  $p = .02$ ,  $d = 0.90$  ( $M_{old} = 4,151$ ,  $M_{young} = 2,474$ ). As expected, gazes were almost exclusively confined to the central pair ( $M = 98.7\%$ ).

### Standard trials.—

Performance on standard trials was consistent with earlier work and is not analyzed in detail. The accuracy of standard trial responses did not vary by age, pair type, block, or the interactions ( $ps > .21$ ,  $M = 95.4$ ). Older adults were slower overall and showed slower rates of RT improvement ( $ps < .01$ ).

The retrieval strategy was reported less often by older adults,  $F(1, 34) = 8.47$ ,  $p < .01$ ,  $d = 0.63$ , and for new pairs,  $F(1, 34) = 36.00$ ,  $p < .01$ ,  $d = 0.43$  (see Figure 2). Retrieval use increased over blocks,  $F(9, 306) = 16.61$ ,  $p < .01$ . The retrieval shift was delayed for older adults compared with young,  $F(9, 306) = 2.77$ ,  $p < .01$ , but the age difference did not vary reliably between prelearned and novel pairs. Reports of the both and other strategies were infrequent (<5% of trials), as is typical for this task (see Touron & Hertzog, 2004b) (Failure to obtain a difference in retrieval use between prelearned and unlearned stimuli is consistent with previous research with larger stimulus sets (Touron & Hertzog, 2004a). This outcome demonstrates that metacognitive influences delay strategy shift even when noun-pair learning is sufficient for retrieval strategy



use. Because there were no effects of prelearning on the gaze count or probability variables ( $p > .3$ ), we do not discuss this variable further in the article.).

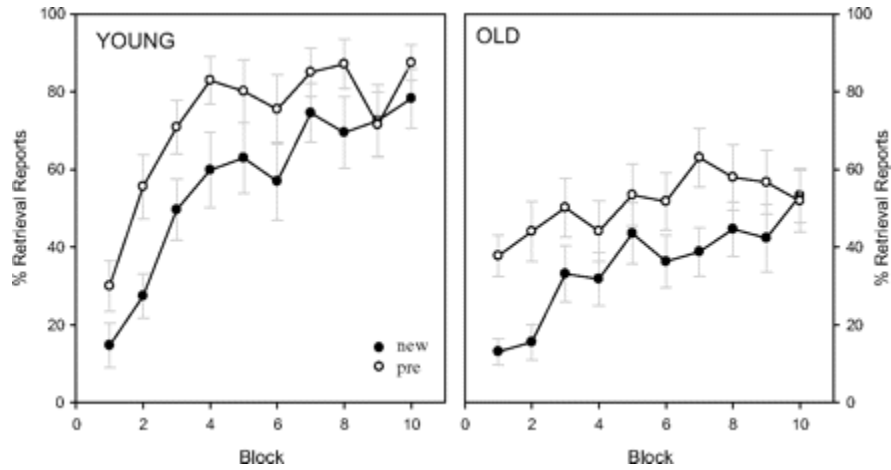


Figure 2.

Percentage retrieval reports (and standard errors) by age (young vs. old), pair type (new vs. prelearned), and training block.

Older adults made more gazes overall compared with young adults,  $F(1, 36) = 9.17$ ,  $MSE = 2.63$ ,  $p < .01$ ,  $d = 0.44$  (see Table 2). More gazes were made for reported scan trials compared with retrieval trials,  $F(1, 36) = 92.20$ ,  $p < .01$ ,  $d = 1.66$  (a very large effect) and to the lookup table compared with the central probe,  $F(1, 36) = 40.16$ ,  $p < .01$ ,  $d = 0.78$  (Note that the number of fixations within a gaze did not vary by age ( $p = .3$ ) or reported strategy ( $p = .6$ ) but did vary by location,  $M_{table} = 3.1$ ,  $M_{probe} = 1.7$ ,  $F(1, 20) = 30.93$ ,  $p < .01$ . No interactions approached reliability. As noted earlier, gaze durations did not vary by age. Age differences in gaze counts are therefore a primary contributor to age differences in RT.). The location by age and location by strategy interactions were also reliable,  $F(1, 36) = 8.71$ ,  $p < .01$  and  $F(1, 36) = 97.14$ ,  $p < .01$ , respectively, with greater disparity between probe and table gazes for older adults and for reported scan trials. Older adults showed more gazes to the table compared with young adults. More gazes to the table occurred when scanning was reported compared with when retrieving, supporting the validity of the strategy self-reports. Pursuant to the main goal of this article, gazes to the lookup table occurred on some reported retrieval trials, particularly for older adults. Gaze counts after reported retrieval were not reliably greater than zero for young adults ( $p = .39$ ) but were reliable for older adults ( $p < .01$ ), who showed an average of two gazes to the lookup table on trials for which they reported memory retrieval.

**Table 2.**

Gaze Counts (and standard errors) by Age, Trial Type, Location, Strategy Report, and Condition

Standard trials

Young

Old

Scanned Retrieved Scanned Retrieved

Probe 1.6 (0.03) 1.1 (0.01) 1.7 (0.02) 1.4 (0.03)

Table 3.2 (0.12) 0.5 (0.04) 4.5 (0.09) 2.0 (0.02)

Memory trials

Young

Old

Absent Filled Absent Filled

Probe 1.0 (0.01) 1.1 (0.02) 1.0 (0.01) 1.4 (0.03)

Table 0.1 (0.01) 0.2 (0.04) 0.1 (0.01) 1.1 (0.07)

We also examined changes in gaze counts by reported strategy over blocks. Older adults look up to the table on reported retrieval trials even following extensive task practice. We used SAS PROC MIXED to analyze the full data set to avoid losing cases due to missing data. Gaze counts to the table decreased with training,  $F(9, 321) = 13.48, p < .01$  (see Figure 3). Decreases occurred for both young adults and older adults and for both reported scan trials and reported retrieval trials. Young adults' lookup gaze counts on reported retrieval trials were reliably greater than zero ( $p < .01$ ) for only the first three blocks, not thereafter ( $p > .05$ ), whereas older adults' lookup gaze counts when retrieving remained reliably greater than zero even at the end of training ( $p < .01$ ).

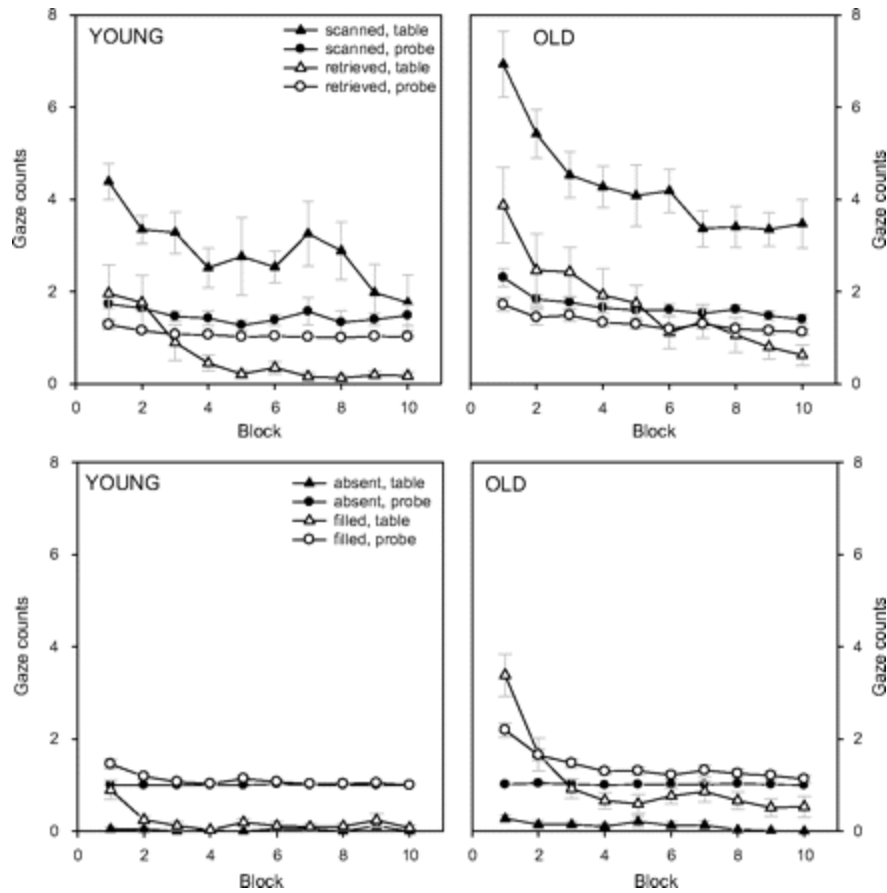


Figure 3.

Top: gaze counts (and standard errors) for standard trials by reported strategy, age, location, and training block. Bottom: gaze counts (and standard errors) for memory test trials by condition (absent or filled lookup table), age, location, and training block.

Given that older individuals gaze the lookup table when reporting memory retrieval, we were interested in whether this behavior occurred consistently. For many trials with retrieval reports, participants did not look up; gazes to the lookup table occurred on only 20.4% of reported retrieval trials for younger adults ( $SE_{yng} = 4.2$ ) but on 51.4% of the trials for older adults ( $SE_{old} = 6.8$ ). If one assumes that any gaze at the lookup table represents a scan, then these data indicate a validity coefficient for retrieval reports of about .8 for younger adults and .5 for older adults. In the Memory trials section, we consider whether such table gazes are information seeking or unintentional. If such table gazes are exclusively purposeful, we would not expect to see any table lookup during memory test trials.

Memory trials.—

Memory trial accuracy and RT over practice were consistent with earlier work (e.g., Touron & Hertzog, 2004a) and hence are not analyzed in detail.

Older adults gazed the lookup table during memory probes, but only when the table was filled with placeholders, an outcome consistent with the idea that older adults' eye movements to the table on reported retrieval trials are not exclusively information seeking (see Table 2).

Participants generally did not gaze at the absent lookup table region, arguing against nonstimulus driven behavioral inertia as an explanation. Older adults made more gazes during memory trials overall compared with young adults,  $F(1, 36) = 18.84$ ,  $MSE = 0.10$ ,  $p < .01$ ,  $d = 0.57$ , and more gazes were also made in the filled table condition compared with the absent table condition,  $F(1, 36) = 34.52$ ,  $p < .01$ ,  $d = 0.81$ . The condition effect was more pronounced for older adults as seen in the reliable age by condition interaction,  $F(1, 36) = 13.32$ ,  $p < .01$ . More gazes were made to the central probe compared with the lookup table,  $F(1, 36) = 335.10$ ,  $p < .01$ ,  $d = 2.08$ . The location by age, location by condition, and three-way interactions were all reliable,  $F(1, 36) = 13.75$ ,  $p < .01$ ,  $F(1, 36) = 12.39$ ,  $p < .01$ , and  $F(1, 36) = 8.06$ ,  $p < .01$ , respectively. Greater disparity was seen between probe and table gazes for older adults and for the absent table condition, and older adults in the filled table condition showed similar gaze frequency to the table and probe. Older adults in the condition with a lookup table filled with irrelevant information showed more gazes to the table compared with young adults.

Older adults' eye movements to the filled table on memory trials continued after extensive task practice (see Figure 3). This effect is consistent with the argument that older adults' eye movements to the table when reporting retrieval on standard trials are automatic rather than purposeful and information seeking. Gazes to the table decreased with practice,  $F(9, 309) = 9.68$ ,  $p < .01$ , but this effect was largely confined to the filled table condition, with gaze counts initially well above floor. Similar to outcomes for the standard trials with reported retrieval, young adults' lookup gaze counts in the filled table condition were reliably greater than zero ( $ps < .01$ ) for only the first two blocks and thereafter indistinct from zero ( $ps > .05$ ), whereas older adults' lookup gaze counts in the filled table condition remained reliably greater than zero even at the end of training ( $p < .01$ ).

Given the evidence that individuals do gaze the table region on memory tests, we evaluated whether this behavior occurred consistently. Gazes to the table region occurred on very few trials in the absent table condition, particularly for younger adults (Myng absent = 3.1%,  $SE_{\text{yng absent}} = 0.7$ , Mold absent = 9.1%,  $SE_{\text{old absent}} = 2.2$ ). Gazes to the filled but uninformative table were more common, especially for older adults (Myng filled = 11.3%,  $SE_{\text{yng filled}} = 2.6$ , Mold filled = 49.7%,  $SE_{\text{old filled}} = 6.7$ ). Note that older adults' mean likelihood of gazing the table with

filled table placeholder memory tests and standard trials with reported retrieval (51.4%) are comparable.

To better determine whether the gazes to the table on retrieval reports conform to unreported scanning or attentional capture, we explicitly compared distributions of gaze counts for different conditions. Figure 4 presents frequency histograms for reported scanning trials, reported retrieval trials, and memory tests. Note that the frequency of trials with multiple gazes during scanning is shifted to the right, relative to the distribution of reported retrieval trials or memory trials. Scanning and retrieval had quite different gaze count distributions even when zero-gaze retrieval trials are ignored. If reported retrieval trials with one or more gazes at the lookup table were based on visual scanning, one would expect similar distributional shape after discounting zero-gaze trials. In contrast, the distribution for reported retrieval with at least one gaze at the table largely overlaps the distribution of table gazes during filled memory tests. These patterns suggest that a similar mechanism of attentional capture to the table, without information seeking, accounts for the table gazes when retrieval is reported on standard trials.

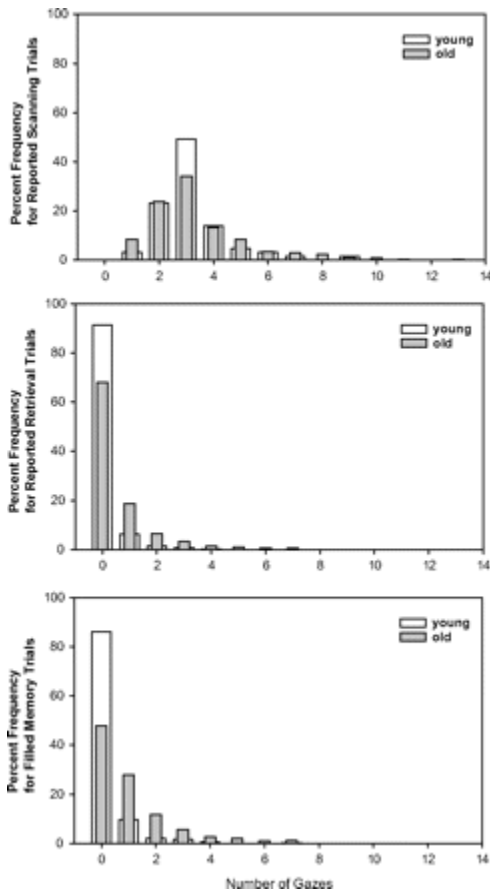


Figure 4.

Histograms of percent frequency of gaze counts to the lookup table for (top) reported scanning trials, (middle) reported retrieval trials, and (bottom) filled memory tests by young adults (white bars) and older adults (gray bars).

## EXPERIMENT 2

In Experiment 1, we inadvertently omitted the table location or AOI for the target pair from the task output file. We were thus unable to examine important questions regarding precise eye movement location with respect to the table target, such as whether participants actually gazed the target in the lookup table when reporting retrieval. Experiment 2 was conducted to further examine the characteristics of table lookup during reported retrieval.

### Methods

Thirteen young adults (18–24,  $M = 19.0$ ) and nine older adults (62–75,  $M = 66.9$ ) were tested in the Experiment 1 condition with standard NP trials and a lookup table filled with placeholders during memory tests (see Table 1 for participant characteristics). All other aspects of the methods were identical to Experiment 1.

### Results

Outcomes from Experiment 1 were replicated. Most critically, older adults again made more gazes to the lookup table when reporting retrieval on standard trials,  $M_{\text{yng}} = 0.7$ ,  $M_{\text{old}} = 1.9$ ,  $F(1, 20) = 5.41$ ,  $p < .05$ ,  $d = 0.77$ , and also gazed the uninformative placeholder table more on memory trials,  $M_{\text{yng}} = 0.4$ ,  $M_{\text{old}} = 1.4$ ,  $F(1, 20) = 6.85$ ,  $p = .02$ ,  $d = 0.70$ . Fewer gazes were again made for reported retrieval trials compared with reported scanning trials,  $M_{\text{retrieval}} = 1.2$ ,  $M_{\text{scanning}} = 2.7$ ,  $F(1, 20) = 43.79$ ,  $p < .01$ ,  $d = 0.99$ .

Recording precise table target location allowed for a more detailed consideration of table lookup when participants report retrieval. Specifically, we were able to confirm that gazes to the lookup table were not information seeking by demonstrating that the target was not typically gazed prior to the participant response. Given the size of the lookup table (six noun pairs) and the average number of table gazes made on reported retrieval trials ( $M_{\text{yng}} = 0.7$ ,  $M_{\text{old}} = 1.9$ ), if gazes to the table were purely automatic and did not involve processing the table stimuli then younger and older adults would be expected to gaze the target with the same likelihood as they would any pair in the table. An appropriate baseline for lookup to a given item can be determined based on the size of the lookup table and the typical number of table gazes (baseline =  $M_{\text{gazes}}/\text{number of}$

pairs). Given the age difference in gazes made on standard NP trials with retrieval reports, the expected baseline percentage was 11.7% and 31.6% of younger and older adults', respectively. Target gazes on retrieval trials were indeed similar to these expected percentages for both young adults,  $M_{\text{yng}} = 11.2\%$ ,  $SE_{\text{yng}} = 6.6$ ,  $t(12) = 0.60$ ,  $p = .56$ , and older adults,  $M_{\text{old}} = 31.7\%$ ,  $SE_{\text{old}} = 7.7$ ,  $t(8) = 0.01$ ,  $p = .99$ . Given that the retrieval trial baseline could include information seeking but uninformative search, we also considered a baseline based on the number of table gazes for filled memory trials. In this case, the expected baseline percentage was 6.7% and 23.3% for younger and older adults', respectively. Target gazes on retrieval trials were again not statistically distinct from the baseline percentages for both young adults,  $t(12) = 2.08$ ,  $p = .06$ , and older adults,  $t(8) = 0.74$ ,  $p = .48$ ; the marginal effect in young adults is arguably less important, given the low incidence of their lookup gazes when retrieving. In contrast, both young and older adults typically did gaze the table target when reporting the scanning strategy,  $M_{\text{yng}} = 94.8\%$ ,  $M_{\text{old}} = 93.5\%$ ,  $F(1, 20) = 0.52$ ,  $p = .48$ .

We also considered whether eye movements within the table region might vary between strategy and trial types. For example, if table fixation is indeed automatic during reported retrieval trials and memory trials, one might expect the initial gaze to focus on the closest table location for retrieval and memory trials. Indeed, the closest table location to the probe pair and central fixation (the middle pair in the bottom row) was the most frequent first gaze location for the majority of our participants regardless of trial type or strategy report ( $M_{\text{scan}} = 55\%$ ,  $M_{\text{retrieval}} = 64\%$ ,  $M_{\text{memory}} = 77\%$ ). The finding of frequent gaze to the closest table location for both scanning and retrieval reports might indicate that attentional capture to the table region typically precedes purposeful scanning behavior.

## EFFICIENCY OF EYE MOVEMENTS

It could be argued that older adults make more gazes when scanning the lookup table because they (1) search more extensively or (2) make more regressions to previously viewed pairs in the table. More extensive search by older adults might indicate greater conservatism in eye movements, whereas more regressions might indicate a less purposeful influence, such as poorer memory of already searched locations (We thank an anonymous reviewer for this suggestion.). Our data supported the latter view. In Experiment 1, older adults did not search more extensively (inspect more table pairs) when scanning compared with young adults,  $F(1, 39) = 3.03$ ,  $p = .09$ ,  $M_{\text{old}} = 3.42$ ,  $M_{\text{yng}} = 3.00$ ,  $d = .59$ , but note a trend in the expected direction. However, older adults did make more regressions to previously viewed pairs in the table when scanning compared with young adults,  $F(1, 39) = 5.79$ ,  $p = .02$ ,  $M_{\text{old}} = 4.85$ ,  $M_{\text{yng}} = 3.79$ ,  $d = 2.60$ .

The data from Experiment 2 allowed us to compare regressions with table targets versus nontargets. Although targets were refixated more often during scanning trials compared with nontargets,  $M_{\text{target}} = 2.62$ ,  $M_{\text{non}} = 0.73$ ,  $F(1, 19) = 252.85$ ,  $p < .01$ , there was no age difference in this pattern ( $p = .31$ ). Older adults demonstrated poorer memory of visual search (but see Kramer et al., 2006) but were not more likely to specifically verify the table target, suggesting that this effect was not due to purposeful double-checking behavior.

It is also possible that age differences in the useful field of view (UFOV; Ball, Beard, Roenker, & Miller, 1988) might impact the efficiency of search in the NP task. Accordingly, we compared the number of gazes per pair between the nearest two table pairs with the fixation and probe (both central positions) versus the furthest four table pairs (the outer positions). Although closer positions were gazed more often,  $F(1, 36) = 162.65$ ,  $p < .001$ , this was not disproportionately the case for older adults,  $F(1, 36) = 1.66$ ,  $p = .21$ . Older adults made more gazes per pair compared with young adults for both close ( $M_{\text{young}} = 0.88$ ,  $M_{\text{old}} = 1.12$ ,  $p < .01$ ) and far ( $M_{\text{young}} = 0.56$ ,  $M_{\text{old}} = 0.73$ ,  $p = .01$ ) table pairs. If eye movements to far locations were more necessary for older adults because of a smaller UFOV, one would predict a greater difference for far pairs. Outcomes suggest that UFOV should not have disproportionately impacted older adults' search efficiency.

## DISCUSSION

As expected under the hypothesis of valid strategy self-reports, more gazes were made to the lookup table on reported scanning trials than on reported retrieval trials for both age groups, and the modal behavior on reported retrieval trials was not to gaze at the lookup table at all. However, some gazes to the lookup table did occur on reported retrieval trials, and this behavior was more likely for older adults. Such an effect could reflect any or all of the following: invalid retrieval self-reports on some trials, an initiated visual search terminated upon retrieval, perseverative scanning behavior, or attentional capture to the table location.

It could be the case that retrieval strategy reports accompanied by table gazes indicate invalid self-reports, such that individuals were either both retrieving and scanning (and should have responded "both") or were scanning yet reporting retrieval. If that were so, then the greater validity of retrieval reports for younger adults (80% of their reported retrievals had 0 table gazes compared with 50% of older adults' reported retrievals) would have interesting implications for interpreting retrieval shift in the NP task. It would suggest that using self-reports actually



overestimates the rate of retrieval shift while underestimating age differences in the rate of retrieval shift. As such, the outcomes of this study would not challenge (and indeed might strengthen) the argument that older adults' manifest a retrieval strategy avoidance (e.g., Touron et al., 2007). By this account, they may even be attempting to conceal that avoidance by reporting more retrieval use than actually occurs.

Nevertheless, we find the pattern of results to be consistent with a hypothesis of valid strategy reports. If participants report having retrieved the answer despite having actually obtained the answer by scanning the table or if participants scan to verify a retrieval (in which case they should report using both strategies), table gazes on reported retrieval trials should include gazes to the target location in the table. However, Experiment 2 showed that the target pair in the lookup table was not gazed more often than chance for these trials for either young or older adults, where chance is determined based on the size of the lookup table and the typical number of table gazes.

Additionally, gazes to the lookup table during memory tests occurred when participants knew that the table would contain no information relevant to the discrimination. It appears that older adults sometimes gaze the lookup table when retrieving in the standard NP task, but this is attentional capture to the presence of the table rather than information-seeking behavior. Gazes to the lookup table during memory tests might indicate attentional capture or behavioral inertia built-up from previous table scanning. Because lookup was noted when the table was filled with placeholders but not when the table was absent, the present data support an attentional capture interpretation, which might stem from age deficits in inhibitory or executive control (see Craik & Byrd, 1982; Hasher & Zacks, 1988). Furthermore, it appears that controlled and purposeful search of the lookup table is more efficient in younger adults compared with older adults and that younger adults are better able to extinguish attentional capture to the filled table region (see Becic et al., 2007; Kramer et al., 2000; Spieler Mayr, & LaGrone, 2006). Consistent with this interpretation, older adults have been shown to be less able to utilize top-down processing (such as the trial-type warning) to inhibit gazes to regions of the visual field that are sometimes but not currently relevant (Whiting, Madden, & Babcock, 2007).

The conclusion that table lookup on reported retrieval trials is automatic rather than information seeking supports the inference that strategy self-reports are valid measures of strategic behavior in the NP task. Providing evidence for the validity of strategy self-reports is critical, as these reports allow for the examination of changes in strategies across training as well as the investigation of how changes in strategy performance relates to changes in learning and metacognitive factors. The present results encourage the continued use of strategy reports to

examine strategic choice, while reinforcing the view that a top–down retrieval avoidance influences delayed retrieval shift in older adults.

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