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Previous studies of metacognitive age differences in skill acquisition have relied exclusively on tasks with a processing shift from an algorithm to retrieval strategy. Thus, it is unclear whether older adults' demonstrated reluctance to shift strategies is specific only to retrieval-based strategies or more general. Haider and Frensch's (1999) alphabet verification task (AVT) is a skill acquisition task which allows for a non-retrieval-based strategy shift. In the AVT a participant verifies alphabet strings such as D E F G [4] L, with the bracketed digit indicating a number of letters to be skipped. In a selective attention condition, deviations occur in only the letter-digit-letter triplet. Thus participants can shift to an abbreviated algorithm in which only the triplet is computed. This is considered a selective attention strategy, as one selectively attends only to the relevant portion of the stimuli. By adapting AVT to include conditions in which shift to a retrieval strategy, a selective attention strategy, or both strategies were possible, this study showed that older adults' shift reluctance is retrieval-specific. Older adults shifted more slowly to a retrieval strategy but more quickly to a selective attention strategy compared to young adults. Strategy confidence and perceived strategy difficulty correlated with both younger and older adults' shift to the two strategies. Perceived speed of the strategy was specifically related to older adults' strategy choice, suggesting that some older adults may avoid retrieval because they do not appreciate the benefits of retrieval. Strategy reports were validated by RT and eye movement data.

METACOGNITIVE AGE DIFFERENCES IN STRATEGY SHIFT: RETRIEVAL AVOIDANCE OR GENERAL SHIFT RELUCTANCE?

by

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CHAPTER I

INTRODUCTION

Many processes in everyday life become more efficient with practice. Improvements often involve a shift from a slow and effortful process, such as taking out your social security card to find the number, to a more efficient and often automatic process, like retrieving that number from memory. Skill acquisition can also be seen in children's learning of multiplication (Siegler, 1988). To solve the problem 3 X 3, children first perform a slow algorithmic process of adding the numbers together, 3 + 3 + 3. With practice the answer 9 is encoded in memory and the child no longer has to perform the algorithm but can instead simply retrieve the answer.

As people age their rate of acquiring new information slows, as does their rate of retrieving new information (Touron, Hoyer, & Cerella, 2001). The use of newly learned information also changes with age. Older adults switch from algorithm to retrieval strategies more slowly than do younger adults; a finding observed on a number of tasks including two-digit multiplication (Lamson & Rogers, 2008), alphabet arithmetic (Hoyer, Cerella, & Onyper, 2003), novel pound (#) arithmetic (Touron et al., 2001), noun-pair associate learning (Rogers & Gilbert, 1997; Rogers, Hertzog & Fisk, 2000; Touron, 2006; Touron & Hertzog, 2004a; 2004b; Touron, Hertzog, & Frank, 2010; Touron, Swaim, & Hertzog, 2007), and reading comprehension (Rawson & Touron, 2009).

Both learning rate and metacognition play a role in older adults' delayed strategy shift (Rogers et al., 2000; Strayer & Kramer, 1994; Touron & Hertzog, 2004a; 2004b). Older adults' use of retrieval strategies is substantially delayed following their learning the requisite information (Touron & Hertzog, 2004a), and retrieval use is influenced by performance incentives (Touron & Hertzog, 2009; Touron et al., 2007) as well as individuals' response criteria and memory confidence (Touron & Hertzog, 2004b). These outcomes suggest that strategy choice is influenced by top-down mechanisms. However, it is unknown whether older adult' delayed strategy shift applies to strategy shifts in general, or only when shifting to a retrieval strategy as in the literature reviewed above. The purpose of this study was to shed light on this issue of general versus specific strategy shift avoidance among older adults.

Skill Acquisition

To understand possible influences on strategy shift and skill acquisition, those processes which underlie automatization must be considered. According to Logan's (1988) instance theory of automatization, both the algorithmic computation as well as attempted retrieval are initiated and performed simultaneously each time a probe (question) is encountered. Instance theory posits that with every successful computation of the algorithm, a new memory trace is created linking the probe to the answer. The next time the same probe (e.g., 3 X 3) is encountered, the algorithm (3 + 3 + 3) is initiated, as is an attempted retrieval of the answer (9). On early trials, retrieval fails or is slow given the limited number of traces in memory. If the correct trace is not activated, memory will fail leaving only the algorithm. But with each new trace created, the likelihood of successfully retrieving the information from memory increases, and eventually successful retrieval occurs prior to the completion of the algorithm. Thus with repeated exposure to the same probe, a person eventually shifts from algorithm to retrieval, but only because retrieval is completed more quickly than the algorithm. This account assumes that retrieval is automatic and resource independent of the algorithm. Instance theory leaves little room for metacognitive influences given that a strategy is not chosen, but rather is purely based on the speed with which each strategy is executed.

In contrast to Logan's (1988) instance theory, Rickard's (1997) component power laws (CMPL) theory offers a strength-based account of skill acquisition. The CMPL theory posits that new traces are not created on subsequent exposures, but the *strength* of the original trace increases with exposure. Furthermore, the CMPL theory claims that dual processing does not occur, but that a strategy is selected for use prior to the initiation of either attempted retrieval or algorithm. Though CMPL theory is agnostic as to how this selection is made, it assumes it is based at least partly on the strength of the memory trace. If the memory trace is weak, retrieval is not attempted and the algorithm is computed. If the trace is strong, retrieval is attempted and the algorithm is not computed. In this single process model, both retrieval and algorithm are assumed to be resource demanding. Support for this view stems from observations that the power function speed up of response times (RTs) are best fit when plotted separately for each strategy (retrieval and algorithm; see also Delaney, Reder, Staszewski, & Ritter, 1998). More recently Bajic & Rickard (2009) have shown that people rarely retrieve during algorithm execution, even when instructed to attempt dual processing on the task, thus further supporting single-processing theories of skill acquisition. Decisions to retrieve have also been linked to familiarity processes such as feeling of knowing (Reder & Ritter, 1992; Schunn, Reder, Nhouyvanisvong, Richards, & Stroffolino, 1997). It has been shown that familiarity with a stimulus is sufficient to induce a retrieval choice even in the absence of knowledge of the answer. This is in direct contrast with instance theory which suggests that successful retrieval from memory determines strategy use. Unlike instance theory, CMPL theory does not explicitly rule out possible metacognitive influences. Given that there is a strategy choice, metacognitive factors could mediate that choice.

Age and Skill Acquisition

One explanation for older adults' slower shift to retrieval is offered by an associative deficit hypothesis (Hoyer et al., 2003; Touron, Hoyer, & Cerella, 2001; 2004). The associative deficit hypothesis suggests that even when the individual items in memory are recalled, older adults struggle to recall the associations that bind units together (Naveh-Benjamin, 2000). Applying this reasoning to skill acquisition, it may be that older adults' difficulty in encoding and recalling the associations between items (which noun was paired with which other noun, the solution to 39 X 46, etc…) prevents them from shifting to a retrieval strategy as quickly as their younger counterparts (Hoyer et al., 2003; Touron et al., 2001; 2004).

While an associative deficit certainly accounts for some age differences in skill acquisition, there is also strong support that metacognitive factors mediate this relationship (Rogers et al., 2000; Touron & Hertzog, 2004a; 2004b). Touron and Hertzog

(2004b) showed that older adults continue using an algorithm strategy even after they have acquired the necessary knowledge to retrieve the answer from memory.

Mental models. Older adults may have different mental models about a task (Touron, et al., 2007) as well as their own abilities (Touron & Hertzog, 2004a; 2004b; 2009; Touron, et al., 2007). A mental model reflects ones' beliefs about a task, the different aspects or components of the task (e.g. the beliefs about possible strategies), as well as about their abilities in relation to the task. For example, a person may believe a strategy is more or less difficult, more or less accurate, and faster or slower compared to another strategy. Likewise they may believe they are more or less capable of effectively using a strategy. They may also have beliefs about task performance, such as it being more (or less) important to be faster versus more accurate. The correlation between older adults' confidence in using a retrieval strategy and their actual retrieval use (Touron & Hertzog, 2004a; 2004b; 2009; Touron, et al., 2007) indicates that mental models about one's own abilities on a task can influence strategy shift.

Hertzog, Touron, and Hines (2007) showed that older adults often underestimate the amount of time required to perform an algorithm. This underestimation was related to greater retrieval reluctance. Thus, through poor RT monitoring, older adults may form inaccurate mental models of available strategies. That is, they may use an algorithmic strategy because they fail to see the benefits of shifting to retrieval.

Touron and Hertzog (2004a) manipulated the cost/benefits ratio for retrieval shift. When the algorithm was more effortful and time consuming, older adults were less retrieval reluctant. Considering age differences in time estimation, Touron and Hertzog

(2004a) may have made the RT difference in algorithm and retrieval more salient such that older adults recognized the algorithm as being substantially slower. That is, when the algorithms' inferiority (in terms of time and effort) was more salient, older adults may have formed different mental models compared to when the benefits were more subtle.

Monetary incentives have also been shown to increase shift to retrieval in older adults (Touron, et al., 2007). Incentives may alter the mental model for older adults who fail to recognize the benefits of retrieval, with shift favored because of monetary incentives and not performance gains. Incentives may also emphasize the goal of performing quickly.

Retrieval Avoidance vs. General Shift Reluctance

Several mechanisms for older adults' reliance on an algorithm over a retrieval strategy have been examined. Older adults avoid memory strategy use despite the fact that they can discriminate learned from unlearned information (i.e., relative accuracy of monitoring is intact; Touron & Hertzog, 2004a). However, older adults report less confidence in their ability to use retrieval-based strategies even when their performance is equivalent to young adults' (i.e., absolute monitoring accuracy is underconfident), and this decreased confidence correlates with slower shifts to retrieval (Hertzog & Touron, 2011). Older adults' retrieval avoidance may also reflect a general tendency toward conservative criterion setting. For example, older adults are slower but more accurate compared to younger adults on simple tasks, and also less willing than young adults to sacrifice speed for accuracy on these tasks (Hertzog, Vernon & Rypma, 1993; Strayer &

Kramer, 1994). As mentioned above, older adults may also favor the algorithm strategy because they underestimate its cost (Hertzog et al., 2007).

While these explanatory mechanisms have been examined for and interpreted from the perspective of specific retrieval avoidance, it remains possible that older adults have a more general reluctance to shift strategies. According to a general shift reluctance hypothesis, older adults are globally reluctant to change their task approach once they have begun using any particular strategy (Spieler, Mayr, & Lagrone, 2006). It has been demonstrated that older adults show a greater switching cost (Kramer, Hahn, & Gopher, 1999), and thus may be less likely to switch tasks voluntarily (Arrington & Logan, 2004; 2005). Spieler and colleagues (2006) demonstrated that older adults continued to fixate previously necessary but now irrelevant task cues, and that this continued reliance on task cues increased older adults' response latencies. This behavioral inertia depended upon the presence of the cue; when the cue was removed older adults ceased to fixate the cue region (see also Touron, et al., 2010). The stimuli used to carry out algorithmic strategies in strategy shift tasks (i.e., the look-up table, letter strings, or multiplication problems) could drive a cue-dependent task-set inertia which explains older adults' reluctance to shift strategies.

Whether older adults' shift reluctance is retrieval-based or more general is unclear because all available research examined metacognitive influences on older adults shift to retrieval. What is necessary to explore the specific versus general nature of older adults' shift reluctance is a single task that allows for a shift to both a retrieval-based and to a non-retrieval-based strategy.

Alphabet Verification Task

The alphabet verification task (AVT) developed by Haider and Frensch (1996) has been used to study skill acquisition and strategy shift in young adults, and involves a shift to a more efficient but non-retrieval-based strategy. In the AVT participants verify the alphabetical correctness of stimuli which contain a series of letters followed by a bracketed number, then another letter (e.g., B C D [4] I). The bracketed number represents the number of letters to be skipped before continuing the string. In the example 'B C D [4] I,' the participant should skip the four letters after D (i.e., B C D [skip E F G H] I), so this stimulus is in correct alphabetical order. The final, letter-digit-letter sequence is called the triplet (e.g., D [4] I). Haider and Frensch (1996) instructed participants that deviations from alphabetical correctness could occur at any point in the string; inside the triplet (e.g., B C D [4] J, where J is alphabetically deviant because I should follow D [4]) or outside the triplet (e.g., B C E [4] J, where E is deviant because D should follow C). Deviations actually only occurred in the last position, however, so participants could perform the task more quickly if they only computed the triplet portion of the string. Haider and Frensch (1996) refer to this as a selective attention strategy, because the participant selectively attends only to the relevant portion of the stimuli. Some participants spontaneously discovered and employed the selective attention strategy with practice, which Haider and Frensch (1996) took as evidence that selective attention can contribute to skill acquisition.

Outside the laboratory, selective attention strategies have been observed in various areas of expertise (Haider & Frensch, 1996). For example, expert chess players selectively attend only to relevant chess pieces when considering a move, whereas novice chess players tend to scan the entire board before considering a move (Frensch & Sternberg, 1991). Thus, selective attention is comparable to retrieval in that both reduce RTs, reduce effort, and are used in everyday life.

Measuring Strategy Shift

Young adults' shift from an algorithm to selective attention on the AVT has been shown to occur at the global level. That is, when young adults shift to a selective attention strategy for one item they shift to a selective attention strategy for all items henceforth (Gaschler & Frensch, 2007). However, strategy shift from algorithm to retrieval typically occurs at the item-level; that is, shift occurs for items more separately as they are learned (Touron, 2006). Therefore, some items which have not yet been adequately learned may continue to be computed while others which have been learned will be retrieved, although reversions to the initial strategy commonly occur (Touron, 2006). It is thus necessary to measure trial-by-trial strategy use when item-level strategy shifts are possible in order to precisely assess strategy shift. Given that performance measures such as RT improve within each strategy as well as with strategy shift (Delaney et al., 1998; Rickard, 1997), performance data alone are not diagnostic of trial-by-trial strategy use. By asking participants after each trial to indicate which strategy they used, one can more precisely gauge strategy use. Strategy self-reports have previously been validated for various tasks using performance data, which shows that algorithm strategies are slower but more accurate compared to retrieval strategies (Delaney et al., 1998; Hoyer et al., 2003; Rawson & Touron, 2009; Rickard, 1997; 2004; Touron, 2006; Touron

& Hertzog, 2004a; 2004b; 2009; Touron, et al., 2010; Touron et al., 2004; Touron et al., 2007). Strategy self-reports have also been validated using eye-movement data suggesting that participants' eye movements are typically consistent with their reported strategies (Green, Lemaire, & Dufau, 2005; Touron, et al., 2010). The current study uses both performance data and eye movement data to verify strategy self-reports.

The concept of using eye movements to verify strategy use is based on the idea that the eye's point of fixation indicates what one is currently processing, or at least that one cannot process and utilize a stimulus that one has not yet perceived (Buswell, 1935). This concept was elaborated by Yarbus, who noted that the eyes ''fixate on those elements of an object which carry or may carry essential or useful information'' (Yarbus, 1967, p. 211). To verify strategy use, the eyes should fixate on the stimulus elements necessary to carry out the reported strategy. Likewise, stimulus elements unnecessary to the reported strategy should not be fixated. While they did not collect strategy reports, Haider and Frensch (1999) used eye movements in conjunction with performance data to gauge strategy use on AVT trials. On early blocks for which aggregate performance data suggested the use of a full computation strategy, gazes were made to the entire string. However, on later blocks for which aggregate performance data suggested the general use of a selective attention strategy, gazes were restricted primarily to the triplet portion of the letter string. In addition to verifying strategy use, eye movement data has revealed several age differences in visual search and task performance behavior. Older adults make more saccadic eye movements (Scialfa, Thomas, & Joffe, 1994), and also engage in more conservative search behaviors such as re-fixating stimuli and making recursive eye movements (Mitzner, Touron, Rogers, & Hertzog, 2010; Scialfa et al., 1994; Veiel, Storandt & Abrams, 2006; Watson, Maylor, & Bruce, 2005). These differences may increase older adults' performance latencies and thus influence observed age differences in skill acquisition. Older adults' increased employment of conservative search behaviors supports the notion that they perform cognitive tasks in a strategically different way than do young adults.

Particularly notable for the proposed study is that older adults make more fixations to irrelevant portions of the visual field (Mitzner et al., 2010; Spieler et al., 2006; Touron et al., 2010). Touron and colleagues (2010) demonstrated that older adults' gazes to irrelevant stimuli can be automatic as opposed to information seeking, making eye movements potentially less diagnostic of retrieval strategy use for older as compared to younger adults. The collection of eye movements and performance data as well as strategy self-reports in the current study will allow for an examination of these issues in a separate task domain, as well as allowing a comprehensive validation of reported strategy use in a task for which strategy self-reports have not been previously collected.

Goals and Hypotheses

The primary goal of the study was to determine whether older adults' previously observed reluctance to change strategies on cognitive tasks is the result of general shift reluctance, more specific retrieval avoidance, or some combination of the two. The proposed study utilized an adapted version of the AVT which allows for shift to a retrieval or selective attention strategy. The adapted task used here does not require that participants discover available strategies and pre-learns the information necessary for retrieval-based performance, in order to control age and individual differences in strategy discovery and learning and also limit task time and fatigue from wearing the eye tracker headset. We examined AVT shift rates using between-subjects conditions which vary strategy shift possibilities. In a *control condition*, only full computation of the algorithm was possible. In a *selective attention condition*, Haider and Frensch's (1996) selective attention strategy and full computation were possible. In a *retrieval condition*, retrieval and full computation were possible. In a *choice condition*, retrieval, selective attention and full computation strategies were possible. We expected young adults to shift to a more efficient strategy whenever possible (selective attention or memory retrieval, depending on condition). We expected older adults to shift to a retrieval strategy more slowly compared to young adults. Slower shift to an available selective attention strategy by older compared to younger adults would indicate that older adults' slower strategy shift is influenced by general shift reluctance. Relatively slower shift by older adults to retrieval in a retrieval condition than to a selective attention strategy in a selective attention condition would indicate a specific retrieval avoidance on the part of older adults. Thus, older adults could exhibit general shift reluctance, specific retrieval avoidance, or both influences. The choice condition in this study was largely exploratory and various outcomes were plausible depending on single strategy condition differences as well as the relative efficiency of each strategy. Strategy choice may depend heavily on the relative costs and benefits of available strategies, which should be based on the distributional separation versus overlap between strategy RTs and accuracy, as well as the accurate monitoring and recognition of such strategy comparisons. Thus older adults' strategy use in the choice condition also had to be evaluated in light of these distributions. For example, if older adults choose a less efficient selective attention strategy over a more efficient retrieval strategy, this would indicate a more substantial role of specific retrieval avoidance for older adults' slower strategy shifts.

CHAPTER II

METHODS

Participants

One hundred nine young adults (ages 18-21) and 86 older adults (ages 60-75) were randomly assigned to one of four strategy conditions: control, memory, selective attention, and choice. Younger adults were general psychology students receiving course credit for participation. Older adults were recruited from the community and received a modest honorarium of $30 (approximately $10 per hour) for participation. All participants were screened for near visual acuity of at least 20/50 and older adults were pre-screened for health issues. Participants diagnosed with dementia or memory loss or taking medications that affect memory or alertness were excluded from the study. Participants reporting factors which complicate eye tracking, including glaucoma, cataracts, colored contacts and transitional lenses were also excluded from the study.

Twenty-four young and seven older adults were excluded from analysis due to poor performance, computer errors, and indications of disbelief or misunderstanding of instructions.[1] Participants removed from analysis were replaced, resulting in roughly twenty participants per age X condition cell.

Table 1
Demographics

	Younger adults								Older adults							
	Control		Retrieval		Selective Attention		Choice		Control		Retrieval		Selective Attention		Choice	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
N	23		19		21		22		20		20		20		20	
Age	19.3	1.45	19.5	0.75	19.4	2.23	19.0	1.34	65.7	2.61	65.6	4.11	66.4	3.93	69.5	3.43
Education	13.0	1.24	12.7	0.75	12.8	1.09	12.7	1.16	16.3	1.98	16.4	2.28	15.3	2.51	15.0	2.42
Health	0.87	0.96	0.42	0.61	0.67	0.58	0.64	0.49	0.33	0.58	0.30	0.47	0.55	0.60	0.25	0.44
DS	65.7	8.63	61.4	7.77	63.8	7.82	63.5	10.61	51.9	10.79	53.3	9.37	51.0	10.63	51.2	9.00
DS recall	7.87	1.74	7.42	1.64	8.24	1.04	7.82	1.37	6.05	2.65	6.20	2.40	6.45	1.93	6.45	2.31
Voc	29.1	3.48	29.1	3.23	28.7	3.17	27.8	3.26	35.0	2.46	33.7	2.92	34.8	2.71	33.8	2.71
Meds	1.04	1.15	0.95	1.31	0.67	1.20	1.23	1.88	2.71	1.90	2.20	1.85	2.60	2.06	2.30	1.22
Fatigue	2.63	0.87	2.67	1.37	2.50	1.20	3.44	1.21	4.00	1.17	3.83	0.69	3.63	0.87	4.50	0.67
HG Fatigue	3.05	1.19	3.11	1.24	2.79	1.32	3.65	1.28	4.35	0.97	3.78	1.13	3.89	1.17	4.58	0.67
HG Disc	3.05	1.05	2.78	1.40	2.90	1.26	3.00	0.97	4.29	1.07	3.22	1.31	3.84	1.18	4.42	0.75

Note. Education = Years of education; Health = 1-4 Self-reported health with lower being better; DS = Digit-symbol substitution task; Voc = Shipley’s vocabulary test; Meds = Number of medications taken daily; HG = headgear, Disc = discomfort.

Participant characteristics can be found in Table 1. The mean age for older adults was greater in the choice condition compared to the other three conditions (all *t*s > 3.5, *p*s < .001, *d*s > 1.01). Older adults were more educated, *t*(165) = 10.54, *p* < .001, *d* = 1.60, rated themselves as healthier on average, *t*(165) = 3.30, *p* = .001, *d* = 0.53, took more medications on average, *t*(165) = 5.93, *p* < .001, *d* = 0.92, and scored higher on the Shipley's Institute of living vocabulary test, *t*(165) = 11.94, *p* < .001, *d* = 1.87. Older adults completed fewer items on the digit symbol test, a test of associative learning and processing speed, *t*(165) = 8.06, *p* < .001, *d* = 1.27. Older adults also performed worse on the digit symbol recall test, a test of implicit associative memory, *t*(165) = 5.12, *p* < .001, *d* = 0.81. This pattern is similar to that found in other studies (e.g. Touron & Hertzog; 2004a, 2004b).

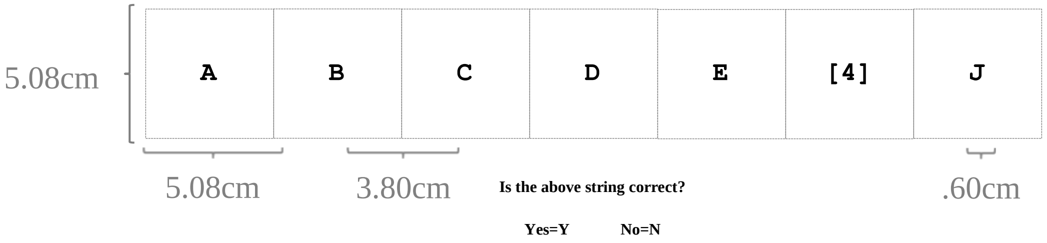
Design

The primary between-subject independent variables were age (old, young) and condition (control, retrieval, selective attention, or choice). The primary within-subject independent variable was Block (1-13) composed of three different phases. Phase 1 included three blocks with no condition differences. In Phase 2, participants pre-learned a stimulus set using a study-test procedure. After Phase 2 participants received condition-specific instructions for Phase 3. Phase 3 (Blocks 4-9) varied stimulus string types and strategy response options by condition, allowing for full computations in all conditions, shift to a selective attention strategy in the selective attention and choice conditions, and shift to a retrieval strategy in the retrieval and choice conditions. Dependent variables included (1) number of blocks to reach Phase 2 pre-learning criteria, (2) Phase 3 strategy probe responses (% computation, retrieval, selective attention, or other), (3) RT, (4) accuracy (% correct responses), and (5) gaze count (the number of gazes to the triplet and non-triplet regions separately). Response time, accuracy, and gaze count data in Phase 3 were examined overall and separated by reported strategy.

Stimuli and Apparatus

The stimulus set consisted of 333 pseudo-randomly selected alphabet strings (117 true and 216 false). Five string lengths were included, triplet only (e.g., G [4] L), triplet +1 (e.g., F G [4] L), triplet +2 (e.g., E F G [4] L), triplet +3 (e.g., D E F G [4] L), and triplet +4 (e.g., C D E F G [4] L). Strings of different lengths allow for the calculation of addend effects, as longer true strings should have systematically longer RTs compared to shorter strings when the full computation strategy is used, but not when the selective attention or retrieval strategies are used. True strings contained an alphabetically correct triplet (e.g., G [4] L) preceded by 0-4 letters in correct alphabetical order (e.g., D E F G [4] L). The bracketed number in each string was either a 4 or 5; which was balanced across string lengths and blocks. False strings contained deviations from alphabetical order either in the triplet or in the preceding 1-4 letters.[2] False strings contained only one point of deviation, and deviation placement was roughly counterbalanced via random string selection.

Participants were seated in front of a Dell computer with LCD monitor at a distance of roughly 61cm. Resolution for the computer screen was set to 1024 X 768. Participants responded via key presses to stimuli presented via a Visual Basic 6.0 program which recorded participant RT to the nearest ms while also recording trial stimuli and accuracy. Eye movements were recorded via an Applied Sciences Laboratories (ASL) head-mounted eye-tracker (model H6HS with eye-head integration) recorded at a sampling rate of 120 Hz. Letter strings appeared in 22 point bolded courier new font (see Figure 1). This font was chosen because each letter in courier new font is of equal width and would thus subtend the same visual angle (0.56°). The individual letters in the stimuli were 3.8cm apart, producing a visual angle roughly of 3.6° between letters. This is comparable to Haider & Frensch's (1999) Experiment 2 with 3° visual angle between stimuli.



Is the above string correct?

Yes=Y No=N

Figure 1. Screen shot of AVT task with superimposed distances and areas of interest (AOIs).

Procedures

All participants first completed a consent form followed by a computerized demographics questionnaire containing health and lifestyle information, the Lighthouse Test of Near Visual Acuity second edition (Bailey, 1978) to ensure at least 20/50 near visual acuity, and a battery of basic cognitive ability tests including Shipley's Vocabulary Test (Zachary, 1986) and the WAIS-R Digit-Symbol subtest (Wechsler, 1981).

After a short break, participants completed a 9-point calibration (Appendix A) of the eye-tracker followed by the AVT computer task. All participants first received standard AVT instructions (Appendix B) followed by an instruction quiz (Appendix C). If any quiz items were not answered correctly, the experimenter indicated which items were incorrect and allowed the participant to review the instructions and ask questions as needed. Only after the participant both completed the quiz error-free and indicated that they understood the instructions did Phase 1 of the experiment begin. In Phase 1, all participants completed three blocks of 30 AVT trials, each block containing three mini-blocks of 10 trials containing one true and one false string for each of five lengths (triplet plus zero, one, two, three or four additional letters). Deviation locations occurred both inside and outside the triplet, with deviation placement occurring pseudo-randomly and balanced by phase across locations for each string length with any imbalance occurring randomly (Appendix D). Phase 1 strings were presented only once each and were not repeated in Phase 3. In keeping with Haider and Frensch (1996; 1999), error feedback was provided after every trial via a 1,000ms “ERROR” message and percent error feedback and mean RT were provided after each block. Each trial was preceded by a 500ms fixation cross displayed in the center of the screen; participants responded to the question “Is the following string alphabetically correct?” via key press using the ‘.’ and ‘/’ keys labeled ‘Y’ and ‘N’ respectively to indicate yes or no. Between blocks participants were offered a short rest break, and the eye-tracker was recalibrated if necessary.

Following Phase 1, all participants received Phase 2 pre-learning instructions (see Appendix E). Participants then memorized six strings via a study-test procedure until they were accurate on at least 11 of 12 trials within a test block containing one true and one false instance of each string. Two strings of each length were used to prevent memorizing/responding based on string length alone. By using strings of triplet +0, +2, or +4 we allow for the calculation of addend effects (as described above) while minimizing the number of total stimuli to be remembered. Since the resulting strings all contain an odd number of digits, the central fixation cross for each trial corresponds to the center digit regardless of string length (Phase 1 strings with odd addends were offset to the left). Participants memorized the strings using only the first and last letters to ease memorization and prohibit computation. Criterion testing presented only the first and last letters of the strings (with interior letters and triplets filled with placeholders; see Appendix F).

After completing pre-learning, Phase 3 instructions began. Participants received separate instructions for each condition (see Appendix G). Participants in the *control condition* were informed that the pre-learned strings would not appear in the next phase. Participants in the *retrieval condition* were informed that the strings in the next phase would be those just pre-learned and that they could respond by computing or by memory retrieval. Participants in the *selective attention condition* were informed that the pre-learned strings would not appear in the next phase and also that the deviations in the next phase would only occur in the triplet portion of the string such that they could respond by computing either the entire string or just the triplet. Participants in the *choice condition* were informed that the strings in the next phase would be those just pre-learned, but that all deviations would occur only in the triplet portion of the string, such that they could compute the entire string, compute just the triplet, or retrieve the answer from memory.

To keep terminology simple and consistent these were referred to throughout training as ‘computation,’ ‘triplet,’ and ‘memory’ strategies, respectively. For the selective attention, memory, and choice conditions, instructions described strategy probes that occur after each trial. The strategy probe instructions varied for each condition given the available strategies. The first letter of each strategy (e.g. ‘c’ for compute) re-labeled the ‘z,’ ‘x,’ ‘c,’ and, for the choice condition, ‘v’ keys.[3] All participants again completed an instructions quiz before being allowed to continue as in Phase 1 (Appendix H).

In Phase 3, participants performed six blocks of 24 AVT trials. Phase 3 stimuli varied by condition as described below and used three string lengths: triplet only, triplet +2, and triplet +4. For all conditions, each Phase 3 block contained eight strings for each of the three lengths, half true and half false. For the control and selective attention conditions, true strings were pseudo-randomly selected from a list of correct strings not appearing in Phase 1 (Appendix I). For the control condition false strings contained deviations in both the triplet and non-triplet portion of the string (Appendix J). Error placement was balanced as in Phase 1. For the selective attention condition, false strings contained deviations only in the triplet portion of the string (Appendix K); nested within each presentation block were six organizational blocks in which each string length occurred once true and once false. For both the retrieval condition and the choice condition, the six pre-learned strings each appeared eight times per Phase 3 block, half as true strings and half as false strings (each beginning and ending with the same letter as one of the 6 pre-learned strings and having the same length as that string); nested within each presentation block were four organizational blocks in which each of the six pre-learned strings occurred once true and once false. For the retrieval condition, false strings contained deviations either inside or outside the triplet (Appendix L). For the choice condition, false strings contained deviations only inside the triplet (Appendix M).

Following the AVT task for all conditions, participants completed a post task questionnaire containing questions about task and strategy performance and beliefs (PTQ) which varied by condition to reflect available strategy options (Appendix N). The entire experiment took young adults less than two hours and older adults less than three hours.

CHAPTER III

RESULTS

The following section begins with Phase 1 analyses to establish the general level of computation-based accuracy and replicate AVT string length effects (Haider & Frensch, 1996; 1999). Phase 2 analyses examine age differences in prelearning. Phase 3 analyses first examine strategy shift data, after which RT and gaze data demonstrate strategy report validity and strategy benefits.

RT and gaze analyses were restricted to correct responses to true strings. RT and gaze analyses were restricted to true strings because RTs and gaze counts would be lower for strings with errors occurring early in the string as opposed to late in the string. Thus, in order to examine string length addend effects, we only analyze strings which must be processed in their entirety before responding (i.e., true strings). Incorrect responses include accidental key presses or faulty processes which are not of interest to this study, and are therefore not examined. Participant medians were examined for RTs to reduce the impact of outliers and adjust for positive skew typical of RT data. RTs were analyzed using SAS Proc Mixed to account for missing data. Because the assumption of sphericity did not hold, *p*-values for within subjects effects are Greenhouse-Geisser corrected *p*-values.

For gaze data, areas of interest (AOIs) were defined as a 5.08cm square box around each element in the AVT string, producing a 1.3° margin of error around each stimulus letter/number. Continued eye positions within an AOI constituted a fixation. A gaze was defined as the time between the onset of the first fixation within a given AOI and the onset of the first fixation outside the AOI. Gazes outside the AOIs were excluded. Pupil diameters of zero lasting more than 100ms were considered blinks and not analyzed. Participants were removed from gaze analyses (but were retained for non-gaze analyses) if more than 30% of their gazes occurred outside our AOIs[4]; this suggests poor calibration of the eye-tracking equipment. In all, this excluded 32 younger and 16 older adults from the gaze analyses (37.6% and 20.0%, respectively).[5] For each participant, blocks with more than 30% of the gazes occurring outside the AOIs or for which the technician noted inadequate tracking were removed. This excluded an additional 6% of all blocks across Phases 1 and 3 combined. Gaze counts to the non-triplet region were used to validate strategy reports for Phase 3; more gazes were expected on longer strings when computing but not when using retrieval or selective attention. Gaze counts to the triplet region and gaze duration data can be found in Appendix O; these did not inform the questions of interest so are not discussed further.

Phase 1 Baseline Computation Measures

Accuracy. To examine age differences in computation accuracy and increases in accuracy over blocks, Phase 1 accuracy was analyzed using a 2 (age: young, old) X 3 (Phase 1 block) repeated measures GLM (general linear model)[6]. Both younger and older adults were highly accurate, although young were more accurate than old, $F(1, 163) = 4.17$, $p = .043$, $d = 0.24$; $M_{young} = 94.5$, $SE_{young} = 0.34$, $M_{old} = 93.0$, $SE_{old} = 0.45$. A main effect of block, $F(2, 326) = 11.08$, $p < .001$, resulted from accuracy improving from

Block 1 to Block 2, *t*(164) = 3.02, *p* = .003, *d* = 0.26; M_{block1} = 92.4, SE_{block1} = 0.56, M_{block2} = 94.2, SE_{block2} = 0.45, but not from Block 2 to Block 3, *t*(164) = 1.31, *p* = .189; M_{block3} = 94.8, SE_{block3} = 0.41. The Age X Block interaction was not reliable, *F* < 1.

Response times. Longer strings should result in longer RTs, and RTs should decrease over blocks as computation becomes more efficient. To examine these patterns, Phase 1 RTs were analyzed using a 2 (age: young, old) X 3 (Phase 1 block) X 5 (string length: +0, +1, +2, +3, +4) repeated measures GLM. The main effect of age was not reliable, *F*(1, 158) = 2.13, *p* = .146. As predicted, a main effect of block, *F*(2, 316) = 146.62, *p* < .001, resulted from incrementally faster RTs over blocks (all *p*s < .001, *d*s from 0.21 to 2.89; see Figure 2).The Age X Block interaction was not reliable, *F*(2, 316) = 2.20, *p* = .118.

As predicted, a main effect of length, *F*(4, 632) = 29.68, *p* < .001, was generally driven by an increase in RT with longer strings (see Figure 2 left panel).[7] None of the interactions were reliable: Age X Length, *F*(4, 632) = 2.19, *p* = .073, Length X Block, *F*(8, 1264) = 1.22, *p* = .291, Age X Length X Block, *F* < 1.

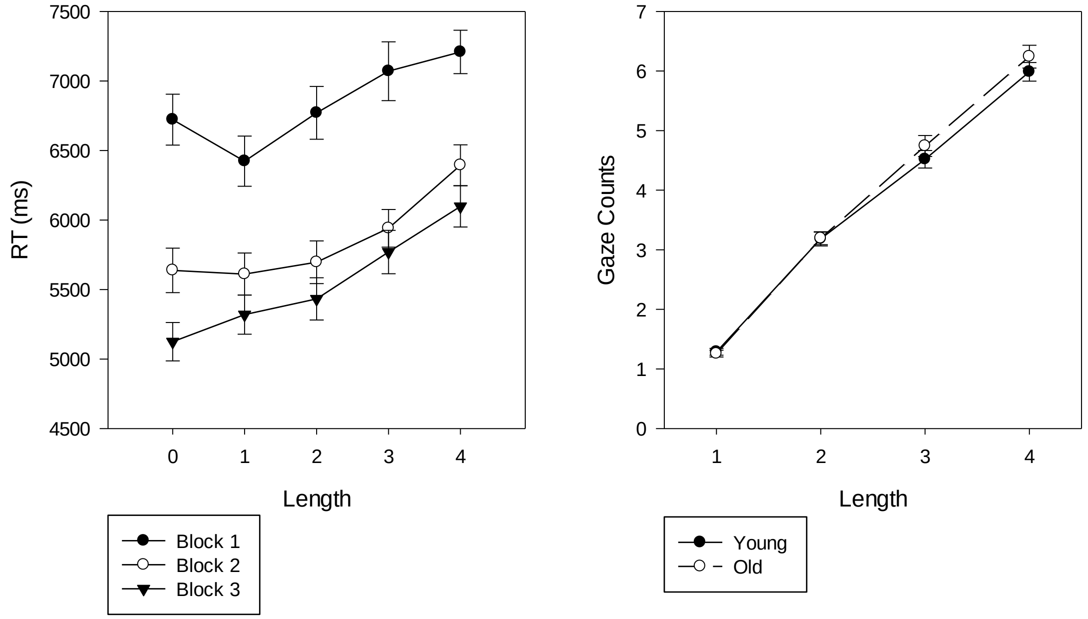


Figure 2. Phase 1 Results. Left panel: Means of median response times (RT) in ms and standard error bars by block and length. Right panel: Phase 1 gaze counts to the non-triplet region by age and length. Length is the number of letters in addition to the triplet.

Gaze counts. Longer strings should result in more gazes to the non-triplet region during computation. To examine this, Phase 1 gaze counts were examined for the non-triplet region of the string using a 2 (age: young, old) X 4 (Length: +1, +2, +3, +4) repeated measures GLM. The main effect of age was not reliable, *F* < 1(see Figure 2 right panel). As predicted, a main effect of length, *F*(3, 327) = 473.69, *p* < .001, indicated gaze counts increasing incrementally with length (all *F*s > 200, *p*s < .001, *d*s between 1.18 and 4.99). The Age X Length interaction was not reliable, *F*(3, 327) = 1.17, *p* = .321.

Phase 1 summary. Both older and younger adults were accurate. Older and younger adults RTs did not differ by age but improved over blocks. As in previous research (e.g. Haider and Frensch, 1996; 1999), string length effects were found for both

RTs and gaze counts, indicating that these measures are sensitive to the increased processing demands of computing longer AVT strings.

Phase 2 (prelearning)

We expected older adults would require more study-test trials to reach the 90% prelearning criterion. Contrary to our prediction, older and younger adults did not differ in the number of blocks required to reach the prelearning criterion $t(164) = 0.46$, $p = .649$ ($M_{young} = 1.87$, $SE_{young} = 0.15$; $M_{old} = 1.78$, $SE_{old} = 0.15$). However, older adults ($M = 2568$, $SE = 137$) took longer to respond during prelearning compared to young adults ($M = 1532$, $SE = 40$), $t(164) = 7.43$, $p < .001$, $d = 1.14$. The finding of no age difference in blocks to criterion is not novel (Hines, Hertzog, & Touron, in press). Older adults may have spent more time studying the strings, but we cannot address this possibility as study time was not recorded.

Phase 3

Phase 3 analyses first compare strategy shift between the retrieval versus selective attention conditions, then examine strategy use in the choice condition, followed by comparisons across the choice versus retrieval and choice versus selective attention conditions. Analyses for accuracy, RT, and gaze counts are then broken down by condition to validate strategy reports and examine the benefits of each strategy. Comparisons between condition RTs are then examined. Lastly, metacognitive ratings are examined between strategies and conditions.

Self-reported strategy use. Strategy use was computed as percentage of trials for which retrieval/selective attention strategies were used (excluding “other” reports, which removed 1.46% of trials). Because “other” responses were removed prior to calculating percent strategy use, strategy use is thus the percent retrieval/selective attention use out of all “non-other” responses and the corresponding value for computation is 100 minus this percentage. In analyses comparing selective attention and computation use, we removed triplet-only strings because for these strings the selective attention and computation strategies are the same.

General vs. retrieval specific shift reluctance. A retrieval specific shift reluctance account predicts that older adults will use less retrieval compared to young but will not use less selective attention compared to young (age x condition interaction). A general shift reluctance account predicts that older adults will use less retrieval and less selective attention compared to young (main effect of age only). Both retrieval specific and general shift reluctance could be observed if older adults use both less selective attention compared to young and use less retrieval compared to their older adult counterparts use of selective attention. Block effects are also considered to examine changes in strategy use with practice. To examine this, percentage retrieval/selective attention use for the retrieval and selective attention conditions was analyzed using a 2 (age: young, old) X 2 (condition: retrieval, selective attention) X 6 (Phase 3 block) mixed GLM.

The main effects of age, $F(1, 76) = 1.66$, $p = .202$, and condition, $F(1, 76) = 3.71$, $p = .058$, were not reliable (see Figure 3). However an Age X Condition interaction $F(1, 76) = 11.70$, $p = .001$, resulted from young adults using the selective attention strategy less often in the selective attention condition compared to older adults, $t(40) = -3.77$, $p < .001$, $d = 0.91$, while a reversed trend was found in the retrieval condition with older adults using less retrieval compared to young adults, *t*(38) = -1.51, *p* = .135 (Figure 3). Although older adults used selective attention ten percent more often compared to retrieval, this difference was not reliable, *t*(40) = 1.02, *p* = .309, but may represent a lack of power. While the tests of older adults' retrieval reluctance did not reach significance, older adults did show a greater willingness to use the selective attention strategy compared to young adults, arguing against a general shift reluctance. We consider this finding further in the discussion section.

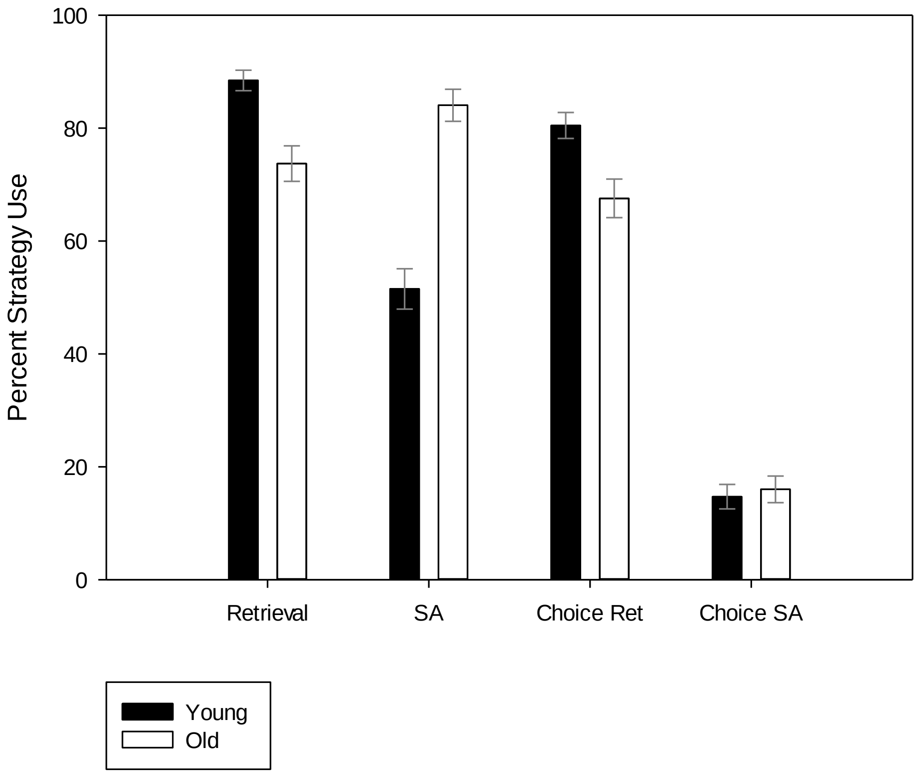


Figure 3. Phase 3 percentage of retrieval and selective attention use (strategy use) and standard error bars by age and condition. Choice Ret = retrieval strategy use in the choice condition; Choice SA = selective attention use in the choice condition.

The main effect of block, *F*(5, 380) = 3.08, *p* = .010, resulted from participants using retrieval and selective attention less often on Blocks 1 and 2 compared to Blocks 3-6 (*ps* < .01; see Figure 4). This rapid strategy adoption is not surprising given that prelearning and selective attention strategy description allowed participants to shift immediately. Retrieval/selective attention use did not differ across Blocks 1 and 2, *t*(79) = 0.66, *p* = .509, or over Blocks 3-6 (*p*s > .250). Interactions with block were not reliable for age, *F*(5, 380) = 1.40, *p* = .223, condition, *F* < 1, or the three-way interaction, *F*(5, 380) = 31.47, *p* = .198.

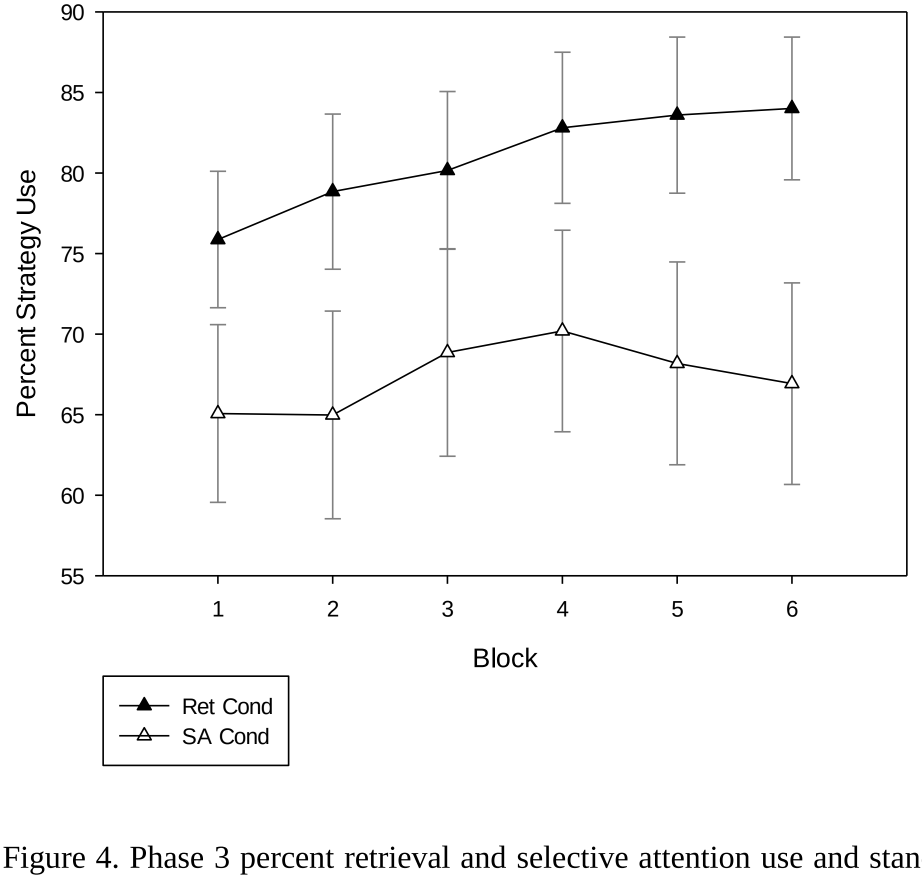


Figure 4. Phase 3 percent retrieval and selective attention use and standard error bars by condition and block. Cond = condition; Ret = retrieval; SA = selective attention.

Choice condition strategy use. Retrieval, selective attention, and computation use were again computed as the percentage of each out of all "non-other" responses. Because the three strategies summed to 100% strategy use for each participant, only two of the strategies could be compared at a time to avoid having complete dependence among the strategies in the ANOVA. Thus, choice condition strategy use was examined via a series of three2 (age: young, old) X 2 (strategy: retrieval/selective attention/computation) X 6 (Phase 3 block) repeated measures GLMs comparing percentage of retrieval, selective attention, and computation use.

A retrieval reluctance account predicts that older adults will use retrieval less than young. However, whether older adults will use more selective attention than retrieval use may depend upon the RT distributions of the retrieval and selective attention strategies as well as older adults' awareness of these RT benefits. To foreshadow, the retrieval strategy led to substantially faster RTs than did selective attention making retrieval far more efficient than either selective attention or computation in the current study. A general shift reluctance account predicts that older adults will be reluctant to shift to either retrieval or selective attention and should thus use more computation than young adults.

For the comparison of retrieval and selective attention use, the main effect of age was not reliable, $F(1, 40) = 1.49$, $p = .230$. Because the test for a main effect of age collapses across retrieval and selective attention use, this is essentially a test of whether older and younger adults differ in non-computation strategy use, which they did not. A main effect of strategy, $F(1, 40) = 72.94$, $p < .001$, $d = 2.21$, resulted from retrieval being used more compared to selective attention (Figure 3). The Age X Strategy interaction was not reliable, $F(1, 40) = 1.30$, $p = .261$. The planned comparison between old and young for retrieval use was also not reliable, $t(41) = 1.35$, $p = .185$. Thus, there was only a trend towards retrieval reluctance for older adults in the choice condition. Despite older adults' preference for the selective attention strategy over computation in the selective attention condition, they did not typically choose selective attention over retrieval when both strategy shift options were present; suggesting that most older adults understood the differential benefits of retrieval in this task.

Neither the main effect of block, $F(5, 200) = 2.12$, $p = .122$, nor the Block X Age interaction were reliable, $F < 1$. A reliable Block X Strategy interaction, $F(5, 200) = 8.14$, $p < .001$, resulted from a decrease in selective attention use over blocks, but an increase in retrieval use over blocks with the majority of the strategy change again occurring in the first two blocks (see Figure 5).[8] The three-way interaction was not reliable, $F < 1$.

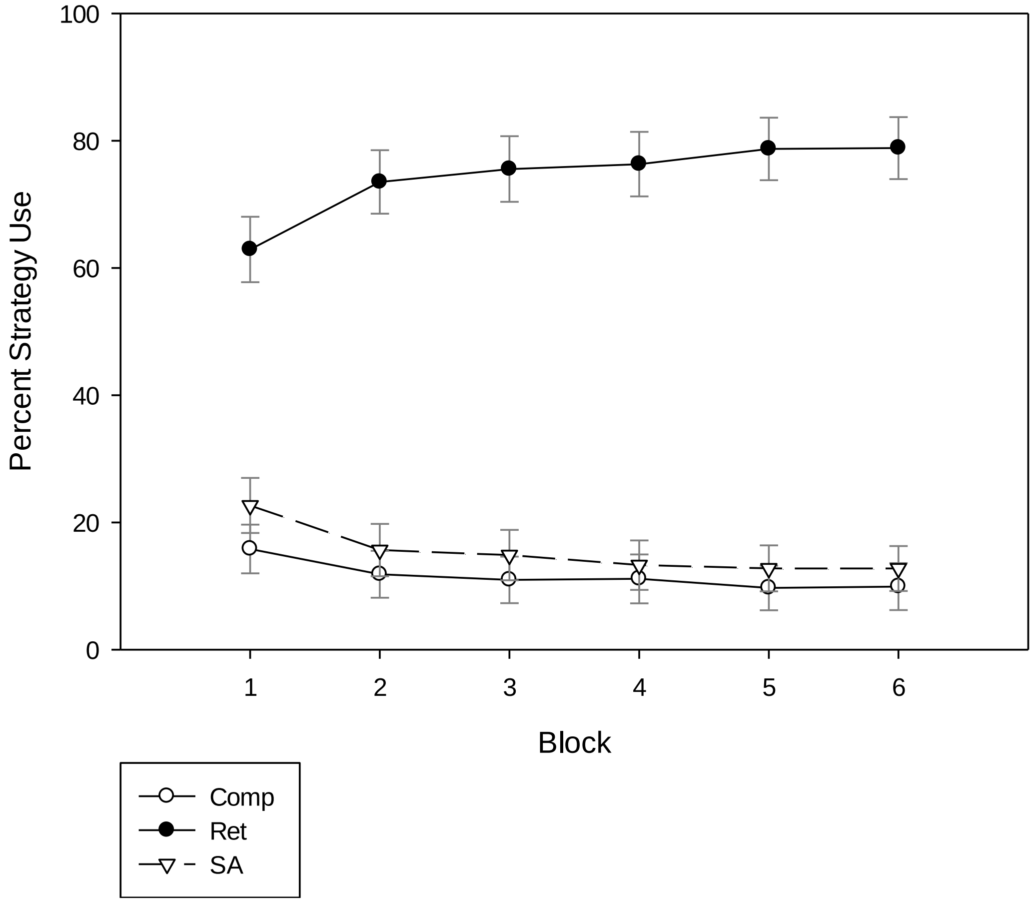


Figure 5. Phase 3 choice condition percent strategy use and standard error bars by strategy and block. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy.

For the comparison of selective attention and computation use, the main effects of age, *F*(1, 40) = 1.73, *p* = .196, and strategy, *F* < 1, were not reliable. A main effect of block, *F*(5, 200) = 8.27, *p* < .001, resulted from selective attention and computation use decreasing over blocks.[9] None of the interactions were reliable: Age X Strategy, *F* < 1, Age X Block, *F* < 1, Strategy X Block, *F*(5, 200) = 1.13, *p* = .324, and Age X Strategy X Block, *F* < 1.

For the comparison of retrieval and computation use, the main effect of age, *F* < 1, was not reliable. A main effect of strategy, *F*(1, 40) = 81.60, *p* < .001, *d* = 2.19, resulted from retrieval being used more than computation. A main effect of block, *F*(5, 200) = 5.57, *p* = .006, was qualified by a reliable Strategy X Block interaction, *F*(5, 200) = 6.26, *p* < .001. As in the earlier analyses this was the result of computation decreasing over blocks but retrieval increasing over blocks. None of the interactions were reliable: Age X Strategy, *F*(1, 40) = 1.88, *p* = .178, Age X Block, *F* < 1, and Age X Strategy X Block, *F* < 1.

In summary, retrieval use was initially high and increased over blocks whereas selective attention and computation use were initially low and decreased over blocks; this was true for both older and younger adults. Selective attention and computation use did not differ from each other; which was also true for both older and younger adults. This latter result speaks against a general shift reluctance account as older adults did not display a general reluctance relative to younger adults to shift to selective attention from the computation strategy. Although older adults used numerically less retrieval compared to young, this difference was not reliable.

Comparison of retrieval and choice condition strategy use. To test whether the presence of an alternative non-retrieval-based option altered retrieval use, we compared retrieval use in the retrieval condition to that in the choice condition. This was done using a 2 (age: young, old) X 2 (condition: retrieval, choice) X 6 (Phase 3 block) repeated measures GLM. There was no main effect of condition, *F*(1, 77) = 1.18, *p* = .282, and no Age X Condition interaction, *F* < 1 (see Figure 3). A main effect of age *F*(1, 77) = 4.49, *p* = .037, *d* = 0.44, indicated that when collapsing across the retrieval and choice conditions the age difference in retrieval use was reliable. Thus, although the use of prelearning and a different memory task (letters rather than word association) in this experiment seem to have reduced older adults' typical retrieval reluctance; it was detectable with additional power.

Similar to the individual results for the retrieval and choice conditions, a main effect of block, *F*(5, 385) = 18.84, *p* < .001, was driven by an increase in retrieval use early in training.[10]

Comparison of selective attention and choice condition strategy use. To test whether the presence of a retrieval-based option altered selective attention use we compared selective attention use in the selective attention condition to that in the choice condition. This was done using a 2 (age: young, old) X 2 (condition: selective attention, choice) X 6 (Phase 3 block) repeated measures GLM. Main effects of age, *F*(1, 79) = 6.86, *p* =.011, *d* = 0.28, and condition, *F*(1, 79) = 65.79, *p* < .001, *d* = 0.39, were qualified by reliable Age X Condition, *F*(1, 79) = 5.84, *p* = .018, and Block X Condition interactions, *F*(5, 395) = 3.99, *p* = .010. Post hoc follow-ups for the Age X Condition interaction indicated that while older adults used more selective attention in the selective attention condition compared to young adults, *t*(40) = 2.99, *p* = .005, *d* = 0.94, this was not true in the choice condition , *t*(40) = 0.16, *p* = .877.

Although the main effect of block was not reliable, *F*(5, 395) = 1.19, *p* = .312, the Block X Condition interaction was reliable and reflects outcomes described in earlier sections, with a reliable block effect in the choice condition but not in the selective attention condition.

Self-reported strategy use summary. Older adults were reluctant to use retrieval but not selective attention when full computation was the only alternative strategy, arguing *for* a retrieval reluctance account and *against* a general shift reluctance account. The presence of a second non-retrieval alternative did not further reduce older adults' retrieval use, suggesting that the selective attention strategy was less appealing when contrasted with a retrieval strategy and may have only been adopted in the choice condition by those unwilling to use retrieval.

Strategy validation and benefits. Phase 3 accuracy, RTs, and gaze counts were examined separately for each condition. Because few participants used computation on later blocks, we compare computation RTs and gaze counts in the first three blocks to retrieval/selective attention RTs and gaze counts in the last three blocks, but restrict these analyses to only those participants who used each available strategy at least once. This restriction resulted in the loss of six young adults and four older adults in the retrieval condition, and two young adults and six older adults in the selective attention condition. SAS Proc Mixed was used to account for missing data as not every strategy was used across each string length.

Control condition. Accuracy, response time, and gaze counts are next examined for the control condition.

Table 2

Phase 3 Accuracy

	Control				Retrieval				Selective Attention				Choice			
	Young		Old		Young		Old		Young		Old		Young		Old	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Comp	94.8	4.26	95.7	2.75	90.5	14.10	78.8	27.10	90.6	9.00	92.0	18.70	93.8	12.10	97.6	3.70
Ret					96.2	4.40	96.6	5.10					97.1	2.40	96.9	6.80
SA									93.0	5.70	92.8	10.40	87.2	26.70	96.0	15.80

Note. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy.

Accuracy. Accuracy did not differ by age, $t(42) = -0.74$, $p = .464$ (see Table 2).

Response times. Because participants had no choice but to compute the entire string in the control condition, longer strings should again result in longer RTs (main effect of length). To examine this, RTs were analyzed using a 2 (age: young, old) X 3 (length: +0, +2, +4) model. The main effect of age was not reliable, $F(1, 41) = 1.27$, $p = .266$ (see Figure 6 left panel). As predicted, a main effect of length, $F(2, 82) = 45.49$, $p < .001$, resulted from an incremental increase in RT with length ($ps < .001$). The Age X Length interaction was not reliable, $F(2, 82) = 1.09$, $p = .334$.

Non-triplet gaze counts. Longer strings should result in more gazes to the non-triplet region during computation (main effect of length). To examine this, non-triplet gaze counts were analyzed using a 2 (age: young, old) X 2 (length: +2, +4) model. A main effect of age, $F(1, 27) = 8.32$, $p =.008$, $d = 0.57$, resulted from older adults making more gazes compared to young (see Figure 6 right panel). As predicted, a main effect of length, $F(1, 27) = 453.72$, $p < .001$, $d = 2.64$, resulted from participants making more gazes on longer strings. The Age X Length interaction was not reliable, $F < 1$.

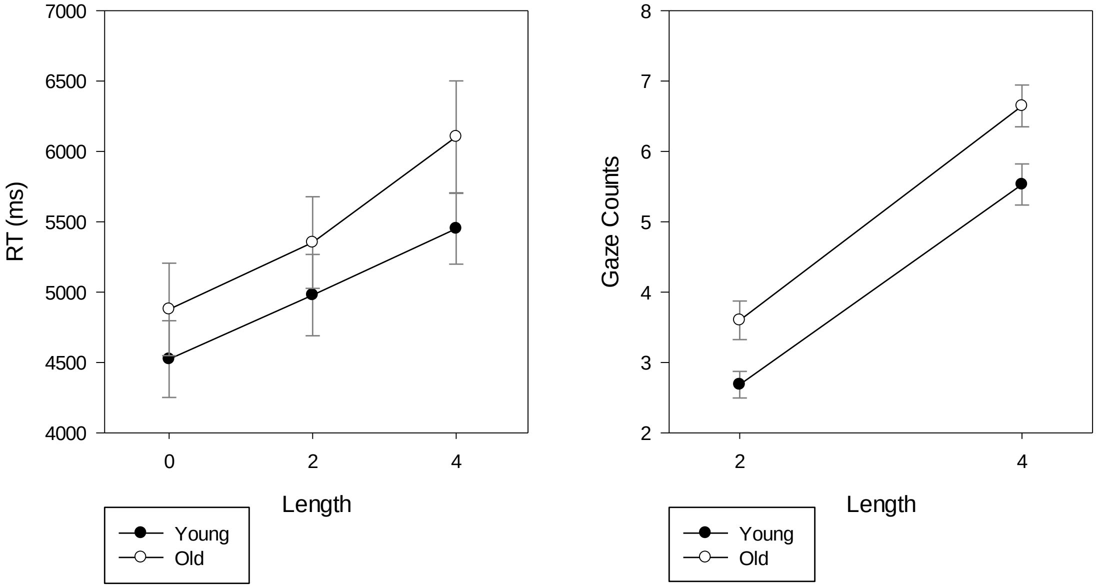


Figure 6. Phase 3 control condition data. Left panel: Means of median response times (RT) in ms by age and length. Right panel: Gaze counts to the non-triplet region by age and length. Length is the number of letters in addition to the triplet.

Retrieval condition. Accuracy, response time, and gaze counts are next examined for the retrieval condition.

Accuracy. Accuracy was analyzed using a 2 (age: young, old) X 2 (strategy: computation, retrieval) repeated measures GLM. The main effect of age was not reliable, *F*(1, 31) = 1.82, *p* = .187. A main effect of strategy, *F*(1, 31) = 8.14, *p* = .008, *d* = 0.75, notably resulted from computation being less accurate compared to retrieval (see Table 2).The Age X Strategy interaction was not reliable, *F*(1, 31) = 2.52, *p* = .122.

Response times. Longer strings should result in longer RTs when computation is used, but not when retrieval is used (Length X Strategy interaction). Also retrieval should result in shorter RTs overall (main effect of strategy). A 2 (age: young, old) X 3 (length:

+0, +2, +4) X 2 (strategy: computation, retrieval) model revealed main effects of age *F*(1, 26) = 12.65, *p* = .002, *d* = 0.50, and strategy, *F*(1, 26) = 306.79, *p* < .001, *d* = 2.40 (see Figure 7 left panel). Young adults were faster compared to older adults and retrieval was faster compared to computation. The main effect of length was not reliable, *F*(2, 52) = 2.74, *p* = .074. None of the interactions were reliable: Age X Strategy, *F*(1, 26) = 3.74, *p* = .064, Age X Length, *F*(2, 52) = 1.42, *p* = .251, Length X Strategy, *F*(2, 22) = 1.59, *p* = .227, and Age X Length X Strategy, *F*(2, 22) = 2.48, *p* = .107.

The lack of a Length X Strategy interaction is surprising; however, few participants frequently used the computation strategy, as a result the RT estimates are relatively unstable. The shorter RTs for reported retrieval trials support the validity of the concurrent strategy reports in the retrieval condition and also suggest a benefit to using retrieval over computation.

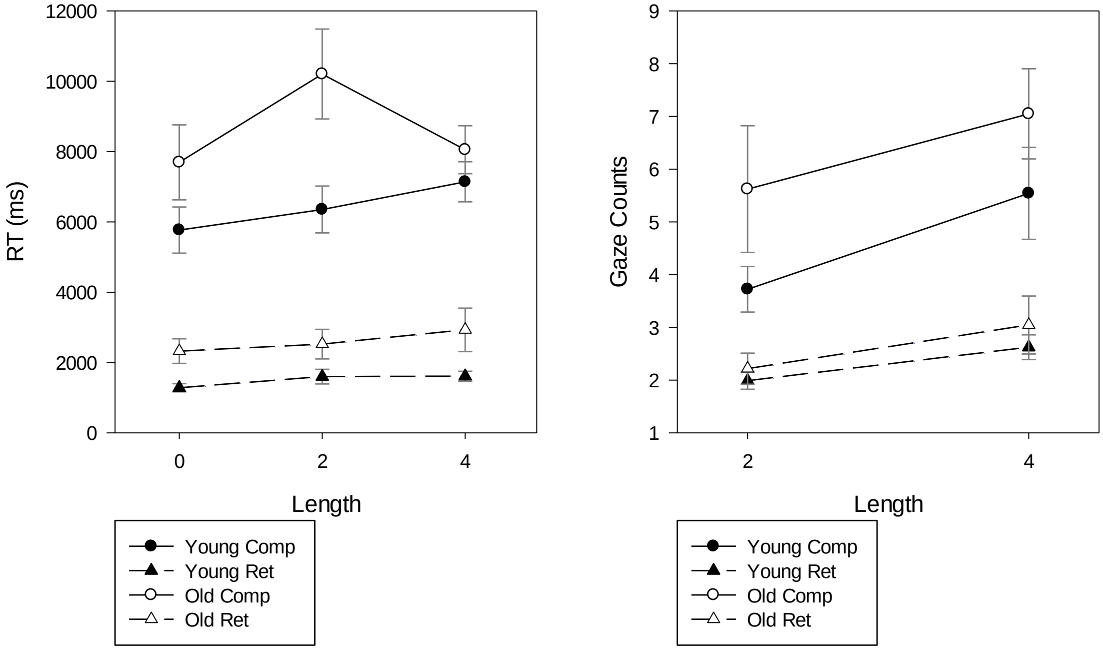


Figure 7. Phase 3 retrieval condition. Left panel: Means of median response times (RT) in ms by age and string length. Right panel: Gaze counts to the non-triplet by age and length. Length refers to the number of letters in addition to the triplet. Comp = computation; Ret = retrieval

The lack of a Length X Strategy interaction is surprising; however, few participants frequently used the computation strategy, as a result the RT estimates are relatively unstable. The shorter RTs for reported retrieval trials support the validity of the concurrent strategy reports in the retrieval condition and also suggest a benefit to using retrieval over computation.

Non-triplet gaze counts. Longer strings should result in more gazes to the non-triplet region when computation is used, but not when retrieval is used (Length X Strategy interaction). Also retrieval should result in fewer gazes overall, as only the first and last letters need to be gazed in order to use retrieval (main effect of strategy). To examine this, non-triplet gaze counts were analyzed using a 2 (age: young, old) X 2 (length: +2, +4) X 2 (strategy: computation, retrieval) model. The main effect of age was not reliable, $F(1, 20) = 2.83$, $p = .108$ (see Figure 7 right panel). As predicted, a main effect of strategy, $F(1, 20) = 66.69$, $p < .001$, $d = 1.42$, resulted from more gazes being made when computation was reported. A main effect of length resulted from fewer gazes on shorter strings, $F(1, 20) = 14.55$, $p = .001$, $d = 0.40$.

The main effect of strategy was qualified by a reliable Age X Strategy interaction, $F(1, 20) = 4.67$, $p = .043$, as well as Length X Strategy trend, $F(1, 20) = 3.85$, $p = .064$. The Age X Strategy interaction resulted from older adults making more gazes compared to young when computing, $t(20) = 2.17$, $p = .035$, $d = 0.87$, but not when retrieving, $t(20) = 0.12$, $p = .909$. The Length X Strategy trend indicated a greater increase in gazes by string length for the computation strategy compared to the retrieval strategy. The three way interaction was not reliable, $F < 1$.

Thus, the validity of retrieval strategy reports was further supported by fewer gazes overall and a trend towards smaller addend effects when retrieving compared to computing. Because older adults made more gazes compared to young when computing but not when retrieving, older adults exhibited a greater reduction in gaze counts when shifting to retrieval.

Selective attention condition. Accuracy, response time, and gaze counts are next examined for the selective attention condition.

Accuracy. Phase 3 accuracy in the selective attention condition was analyzed using a 2 (age: young, old) X 2 (strategy: computation, retrieval) repeated measures

GLM. Accuracy was generally high (*M* = 92.1, *SE* = 2.40; see Table 2). The main effects of age, *F* < 1, strategy, *F* < 1, and the Age X Strategy interaction, *F* < 1, were not reliable.

Response times. Longer strings should result in longer RTs when computation is used, but not when selective attention is used (Length X Strategy interaction). Also selective attention should result in shorter RTs overall (main effect of strategy). To examine this, Phase 3 RT in the selective attention condition were analyzed using a 2 (age: young, old) X 3 (length: +0, +2, +4) X 2 (strategy: computation, selective attention) model. A main effect of age, *F*(1, 31) = 4.85, *p* = .035, *d* = 0.24, resulted from slower RTs for older adults (see Figure 8 left panel). As predicted, a main effect of strategy, *F*(1, 31) = 63.83, *p* < .001, *d* = 0.72, resulted from selective attention being faster than computation. A main effect of length, *F*(2, 62) = 5.17, *p* = .008, resulted from longer RTs for strings of length +4 compared to +0 or +2 (*p*s < .04, *d*s = 0.16 and 0.28 respectively), but no difference between string lengths of +0 or +2 (*p* = .287). These main effects were qualified by reliable Age X Strategy and Length X Strategy interactions. The Age X Strategy interaction, *F*(1, 31) = 13.94, *p* < .001, resulted from older adults benefitting more from the selective attention strategy (*d* = 0.93) compared to young adults (*d* = 0.62), *t*(31) = 2.63, *p* = .013. As predicted, the Length X Strategy interaction, *F*(2, 29) = 4.78, *p* = .016, resulted from a reliable string length effect for computation but not for selective attention.[11]

Faster RTs and the absence of string length effects for the selective attention strategy confirm the validity of the selective attention reports. Interestingly, the selective attention strategy was more beneficial for older compared to younger adults; something we comment on further in the discussion section.

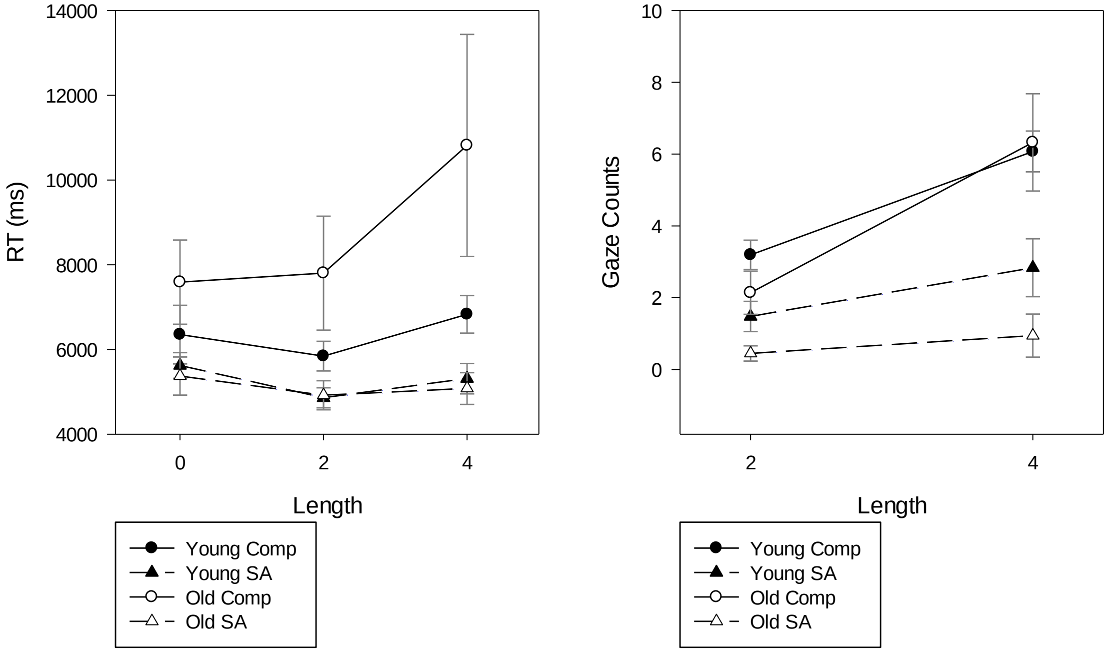


Figure 8. Phase 3 selective attention condition. Left panel: Means of median response times (RT) in ms by age and length. Right panel: Gaze counts to the non-triplet by age and length. Length refers to the number of letters in addition to the triplet. Comp = computation; SA = selective attention.

Non-triplet gaze counts. Longer strings should result in more non-triplet gazes when computation is used, but not when selective attention is used (Length X Strategy interaction). Also selective attention should result in fewer gazes overall (main effect of strategy). Furthermore, if selective attention is completely successful there should be no non-triplet gazes when selective attention is reported (but see Haider & Frensch, 1999). To examine this, non-triplet gaze counts for the selective attention condition were analyzed using a 2 (age: young, old) X 2 (length: +2, +4) X 2 (strategy: computation, selective attention) model. The main effect of age was not reliable, *F*(1, 19) = 1.33, *p* = .264 (see Figure 8 right panel). As predicted, a main effect of strategy, *F*(1, 19) = 50.11, *p* < .001, *d* = 1.34, resulted from more gazes for reported computation compared to selective attention. A main effect of length, *F*(1, 19) = 57.85, *p* < .001, *d* = 0.88, resulted from more gazes on longer strings. However these main effects were qualified by a predicted Strategy X Length interaction, *F*(1, 19) = 16.61, *p* < .001. A post hoc paired *t*-test revealed a greater increase in gaze counts to the non-triplet region for longer strings when computation was used compared to when selective attention was used, *t*(28) = 3.31, *p* = .003, *d* = 1.17. However, the string length effect was only reduced but was still reliable when selective attention was used, *t*(19) = 1.79, *p* = .005, *d* = 0.58. The three way interaction was not reliable, *F* < 1.

Additionally, even when selective attention was used, the mean number of gazes to the non-triplet portion of the string was reliably greater than zero (*M* = 1.52, *SE* = 0.33), *t*(19) = 3.81, *p* = .001. This is consistent with Haider and Frensch's (1999) suggestion that while participants are able to reduce the number of gazes to irrelevant portions of the string, they may not be fully successful at eliminating all such gazes, which may sometimes be relatively automatic (see also Touron et al., 2010). Alternatively, Haider and Frensch (1999) also suggested that some participants may be using the first letter or two to facilitate their computation of the triplet, while still ignoring the majority of the irrelevant information. Both of these explanations are consistent with our finding of a smaller length effect in the selective attention condition, as longer strings could result in a larger “running start” before triplet computation as well as additional automatic gazes. Most importantly, however, is that the mean number of gazes made to +2 and +4 strings when using selective attention were 1.00 (*SE* = 0.27) and 2.00 (*SE* = 0.56) respectively, which is not sufficient to have processed all non-triplet letters. In contrast, the mean number of gazes to the non-triplet region for +2 and +4 strings when computation was used were 2.82 (*SE* = 0.35) and 6.15 (*SE* = 0.55), more than enough gazes to have processed the entire non-triplet region. Thus, in spite of the reliable length effect and greater than zero gaze counts to the non-triplet when selective attention use was reported, these reports do appear to be generally valid as full computation could not have taken place (given the minimal number of gazes to the non-triplet) when selective attention was reported.

Choice condition. Phase 3 accuracy, response time, and gaze counts could not be compared across strategies in the choice condition because few participants used all three strategies. We did examine age and string length effects separately for each individual strategy; comparisons for the computation and selective attention strategies were uninformative because infrequent use reduced stability. Comparisons for the retrieval strategy were largely consistent with those in the retrieval shift condition so are not discussed in detail here (see Appendix P for descriptive statistics). Thus, for the choice condition we will not present strategy validation analyses and instead only examine RT benefits for strategy shift.

RT benefits of retrieval. To assess the benefits of shifting to retrieval, we compared last block retrieval RTs for retrieval and choice condition participants who used retrieval on at least 80% of their Phase 3 trials, with last block RTs for participants in the control condition (who had no option but to use full computation throughout Phase 3). This was done using a 2 (age: young, old) X 2 (condition: retrieval/choice, control) ANOVA. A main effect of age *F*(1, 117) = 7.06, *p* = .009, *d* = 0.31, resulted from young adults (*M* = 2563, *SE* = 253) being faster compared to older adults (*M* = 3181, *SE* = 265). A main effect of condition (essentially a main effect of strategy in this analysis), *F*(1, 117) = 223.02, *p* < .001, *d* = 2.52, resulted from retrieval (*M* = 1654, *SE* = 100) being faster compared to computation (*M* = 5030, *SE* = 255). There was no reliable Age X Condition interaction, *F*(1, 117) = 0.50, *p* = .482. Even when computation was used throughout training, it was never as efficient as retrieval.

RT benefits of selective attention. To assess the benefits of shifting to the selective attention strategy, we compared last block selective attention RTs for selective attention and choice condition participants who used selective attention on at least 80% of their Phase 3 trials, with last block RTs for participants in the control condition (who had no option but to use full computation throughout Phase 3). This was done using a 2 (age: young, old) X 2 (condition: selective attention/choice, control) ANOVA. The main effects of age, *F*(1, 88) = 0.25, *p* = .619, and condition, *F*(1, 88) = 02.16, *p* = .156, were not reliable, nor was the interaction, *F*(1, 88) = 0.93, *p* = .338. Thus we did not find any RT benefit for shifting to selective attention (*M* = 4608, *SE* = 169) compared to when computation also received considerable practice (*M* = 5030, *SE* = 255). This contrasts with the within subject analysis from the selective attention condition, with a few possible explanations. First, few participants continued to use the full computation strategy in the selective attention condition, thus it received far less practice compared to the selective attention strategy—inflating the RT difference. Second, the analysis of RTs for the selective attention condition compared strategies within subject, and thus was more powerful than the current test.

The finding of no selective attention benefit is also somewhat consistent with Haider and Frensch's (1996) findings of no RT separation between their informed and uninformed conditions until after 315 trials (our study included only 234 trials). Also note that all our strings for the control and selective attention conditions were unrepeated, whereas Haider and Frensch used repeated strings and their RT improvements likely represent speed-up due to both retrieval use and selective attention use.

Metacognitive Measures

Results for the post-task metacognitive measures and their correlations with task performance are broken down as follows: We first compared the retrieval and selective attention conditions and then examine the choice condition. Within each of these, we first examined whether mean ratings of difficulty, confidence, and benefits differed across strategies or age groups. Second, we assessed whether these ratings correlate with reported retrieval and selective attention use.

Strategy ratings for retrieval and selective attention conditions. Confidence in the ability to use the strategy, difficulty of strategy use, and how much the strategy improves performance speed were examined using a series of 2 (age: young, old) X 2 (condition: retrieval, selective attention) ANOVAs (see Table 3). All ratings were made using 10 point intervals on scales ranging from 0 (not at all difficult/confident, etc…) to 100 (very confident/difficult, etc...).[12]

For how confident one was to use a given strategy the main effects for age, *F*(1, 76) = 0.44, *p* = .510, and condition, *F*(1, 76) = 2.11, *p* = .150, were not reliable. However, an Age X Condition interaction, *F*(1, 76) = 5.95, *p* = .017, confirmed that younger adults' confidence ratings were lower for the selective attention strategy compared to the retrieval strategy, *t*(39) = 2.75, *p* = .007, *d* = 0.88, whereas older adults' confidence ratings did not differ between the strategies, *t*(39) = 0.70, *p* = .487. Young adults' confidence ratings were also lower for the selective attention strategy relative to older

Table 3

Means and Standard Deviations for Metacognitive Measures

	Younger adults						Older Adults					
	Retrieval		Selective Attention		Choice		Retrieval		Selective Attention		Choice	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Confidence$_{\text{Ret}}$	84.2	22.56			82.7	25.44	72.5	29.14			76.5	24.76
Confidence$_{\text{SA}}$			59.5	32.69	61.8	34.73			79.0	28.45	72.0	28.57
Difficulty$_{\text{Ret}}$	13.2	18.94			14.5	19.48	21.5	23.51			28.0	30.11
Difficulty$_{\text{SA}}$			37.7	26.79	38.6	30.80			23.5	25.75	36.5	33.21
Speed$_{\text{Ret}}$	96.8	9.21			96.4	7.72	82.5	25.08			94.0	9.67
Speed$_{\text{SA}}$			63.6	26.73	27.7	25.40			66.5	34.00	18.5	28.16
Accuracy$_{\text{Ret}}$	71.6	22.78			77.3	22.60	65.0	26.18			75.0	25.40
Accuracy$_{\text{SA}}$			45.0	28.09	52.3	15.36			61.5	36.00	50.0	27.39
Strengthen$_{\text{Ret}}$	84.2	15.67					78.0	28.22				

adults’, *t*(40) = 2.22, *p* = .029, *d* = 0.63, whereas older and younger adults’ confidence ratings did not differ for the retrieval strategy, *t*(38) = 1.24, *p* = .218.

For how difficult one found a given strategy, the main effect of age was not reliable, *F*(1, 76) = 0.43, *p* = .515. The main effect of condition was reliable, *F*(1, 76) = 6.40, *p* = .014, *d* = 0.55, but was qualified by a reliable Age X Condition interaction, *F*(1, 76) = 4.70, *p* = .033, as young adults’ difficulty ratings were higher for the selective attention strategy compared to the retrieval strategy, *t*(39) = 3.32, *p* = .001, *d* = 1.06, whereas older adults’ difficulty ratings did not differ between the two strategies, older adult *t*(39) = 0.26, *p* = .798. Younger adults’ difficulty ratings were also higher for the selective attention strategy relative to older adults’ difficulty ratings for the selective attention strategy, *t*(40) = 2.02, *p* = .047, *d* = 0.54, whereas older and younger adults’ difficulty ratings did not differ for the retrieval strategy, *t*(40) = 1.06, *p* = .294.

For how much one thought a given strategy improved performance speed, the main effect of age was not reliable, *F*(1, 76) = 0.82, *p* = .367. A main effect of condition, *F*(1, 76) = 18.00, *p* < .001, *d* = 0.95, resulted from retrieval being rated faster compared to selective attention. The Age X Condition interaction was not reliable, *F*(1, 76) = 2.33, *p* = .131, but there was a numerical trend in the direction of young adults rating retrieval faster compared to older adults, *t*(38) = 1.70, *p* = .093, there was no age-related trend for the selective attention strategy, *t*(40) = 0.44, *p* = .659.

How much more accurate one found a given strategy was rated relative to the computation strategy (with 0 being less accurate, 50 being equally accurate, and 100 being much more accurate). Therefore this measure is not directly comparable to the others. A main effect of age was not reliable, *F*(1, 76) = 0.69, *p* = .468. A main effect of condition, *F*(1, 76) = 5.06, *p* = .027, *d* = 0.52, resulted from retrieval being rated more accurate compared to selective attention. The Age X Condition interaction was not reliable, *F*(1, 76) = 2.97, *p* = .089, but there was a numerical trend in the direction of lower young adult accuracy ratings for the selective attention strategy compared to the retrieval strategy, *t*(39) = 2.81, *p* = .006, *d* = 1.04, whereas older adults' accuracy ratings did not differ between the strategies, *t*(39) = 0.37, *p* = .710. younger adults' accuracy ratings also tended to be lower for the selective attention strategy relative to older adults', *t*(40) = 1.76, *p* = .083, whereas older and younger adults' confidence ratings did not differ for the retrieval strategy, *t*(38) = 0.69, *p* = .490.

Metacognitive influences on strategy use for retrieval and selective attention conditions. The relationship between the metacognitive ratings of each strategy and actual strategy use were examined via Pearson correlations (see Table 4).

Table 4

Correlations Between Strategy Use and Metacognitive Ratings for Retrieval and Selective Attention Conditions

	Overall	YA	OA	Ret	SA	YA Ret.	OA Ret.	YA SA	OA SA
Conf	**.61**	**.73**	**.49**	**.70**	**.54**	**.93**	**.59**	**.58**	.37
Difficulty	**-.70**	**-.77**	**-.63**	**-.82**	**-.60**	**-.84**	**-.82**	**-.65**	**-.45**
Accuracy	**.52**	**.57**	**.48**	**.51**	**.50**	.37	**.57**	**.49**	.44
Speed	**.50**	**.46**	**.55**	**.59**	**.42**	.27	**.61**	.23	**.60**
Strength				**.50**		**.47**	**.50**		

Note. Bolded correlations are significant at the $p < .05$ level. YA = young adult; OA = older adult; Ret = retrieval condition; SA = selective attention condition; Conf = confidence

Self-reported confidence was positively correlated with both retrieval and selective attention use for both older and younger adults (all *p*s < .05), the one exception being an unreliable correlation between selective attention use and confidence for older adults ($p = .110$). Generally however, participants reporting less confidence in a strategy were less likely to use the strategy.

Self-reported difficulty was negatively correlated with both retrieval and selective attention use for both older and younger adults (all *p*s < .05). Participants reporting that a strategy was more difficult were less likely to use that strategy.

Self-reported benefit to performance speed for a strategy was positively correlated with both retrieval and selective attention use for older (*p*s < .005) but not younger adults (*p*s > .250). Thus, believing that a strategy improved performance speed was related to increased use of that strategy for older adults. Although young adults varied in their ratings of performance benefits for the selective attention strategy, these ratings did not correlate with their likelihood of using the strategy. Instead it appears that confidence and perceived difficulty of selective attention may have primarily driven differences in younger adults' decisions to use selective attention.

Self-reported benefit to accuracy relative to the computation strategy was positively correlated with younger adult selective attention use (*p* = .025) and marginally correlated with older adult selective attention use (*p* = .052). Accuracy ratings were also positively correlated with older adult retrieval use (*p* = .009), but not younger adult retrieval use (*p* = .121). Thus participants were generally less likely to use strategies which they felt were less accurate, which was particularly the case for older adults and the retrieval strategy.

We also asked participants in the retrieval condition how much they felt using retrieval strengthened their memory (0 not at all, 100 very much). There were no age differences in mean ratings, *t*(38) = 0.82, *p* = .416 (see Table 3). However, this measure was correlated with retrieval use for both older and younger adults (*p*s < .05), such that those who retrieved more often were more likely to endorse a belief that retrieval strategy use improves memory.

Summary of metacognitive influences in the retrieval and selective attention conditions. Young adults generally rated the selective attention strategy less favorably compared to older adults. Although older adults typically rated the retrieval strategy numerically lower compared to younger adults, these differences were not reliable. Both young and older adults rated retrieval faster compared to selective attention. Participants generally used strategies they were more confident in and found easier to use. Older adults' strategy use was additionally related to how fast they felt a particular strategy was.

Strategy ratings for the choice condition. Confidence, difficulty, and perceived performance benefit were examined for the choice condition using series of 2 (age: young, old) X 2 (strategy: retrieval, selective attention) ANOVAs (see Table 3).

For confidence ratings, the main effect of age was not reliable, $F(1, 40) = 0.09$, $p = .760$. A marginal main effect of strategy, $F(1, 40) = 3.91$, $p = .055$, suggested greater confidence in the retrieval strategy. The Age X Strategy interaction was not reliable, $F(1, 40) = 1.63$, $p = .209$.

For difficulty, the main effect of age was not reliable, $F(1, 40) = 0.71$, $p = .405$. A main effect of strategy, $F(1, 40) = 7.07$, $p = .011$, resulted from the selective attention strategy being rated as more difficult compared to the retrieval strategy ($d = 0.56$). The Age X Strategy interactions was not reliable, $F(1, 40) = 1.62$, $p = .211$.

For the benefit to performance speed, the main effect of age was not reliable, $F(1, 40) = 2.06$, $p = .159$. A main effect of strategy, $F(1, 40) = 224.64$, $p < .001$, $d = 3.53$, resulted from the retrieval strategy being rated faster compared to the selective attention strategy. The Age X Strategy interaction was not reliable, $F(1, 40) = 0.51$, $p = .480$.

For the benefit to accuracy relative to the computation strategy, the main effect of age was not reliable, $F(1, 40) = 0.23$, $p = .636$. A main effect of strategy, $F(1, 40) = 20.68$, $p < .001$, $d = 1.07$, resulted from the retrieval strategy being rated more accurately compared to the selective attention strategy. The Age X Strategy interaction was not reliable, $F(1, 40) < 0.01$, $p > .999$.

Thus, the retrieval strategy was judged more favorably on average compared to selective attention for all metacognitive measures.

Metacognitive influences on strategy use for the choice condition. Correlations for mean data can be found in Appendix Q. However, for the choice condition it is more informative to examine how within-subject differences in the ratings for the retrieval and selective attention strategy correlate with within-subject differences in the use of those strategies. To examine this each participant's Phase 3 percentage selective attention use was subtracted from their Phase 3 retrieval use. Thus, participants with positive scores on this new measure are those that used retrieval more than selective attention. Participants with negative scores on this measure are those that used selective attention more than retrieval. The same was then done for each participant's ratings of each strategy for confidence, difficulty, speed, and accuracy—subtracting the rating of the selective attention strategy from that of the retrieval strategy. The means and standard deviations for these difference scores are shown in Table 5; correlations between each metacognitive difference measure and the difference in strategy use are in Table 6.

Table 5
Means and Standard Deviations for Choice Condition Metacognitive Difference Scores

			Younger adults		Older adults	
	M	*SD*	*M*	*SD*	*M*	*SD*
Conf	13.1	41.68	20.9	44.82	4.5	36.58
Dif	-16.7	39.74	-24.1	34.05	-8.5	44.18
Spd	71.9	30.75	68.6	29.46	75.5	32.10
Acc	25.0	34.94	25.0	26.72	25.0	42.55

Note. Conf = retrieval confidence – selective attention confidence; Dif = retrieval difficulty – selective attention difficulty; Spd = retrieval speed – selective attention speed; retrieval accuracy – selective attention accuracy. Thus positive numbers mean retrieval was rated higher on average and negative numbers mean selective attention was rated higher on average.

Differences in strategy confidence were positively correlated with differences in strategy use for both younger and older adults (*p*s < .03), indicating that participants who were more confident in their ability to use retrieval compared to their ability to use selective attention used retrieval more than selective attention and vice-versa.

Differences in strategy difficulty were negatively correlated with differences in strategy use for younger, *p* = .019, but not older adults, *p* = .095. This suggests that young adults who found retrieval to be less difficult compared to selective attention were more likely to use retrieval and vice-versa. However, these data suggest that older adults may have weighed the relative difficulty of the strategies less heavily than did young adults when deciding which strategy to use.

Differences in the perceived benefits to performance speed for the two strategies were positively correlated with strategy choice for older, *p* = .017, but not younger adults,

$p = .134$. For interpretation sake, it is important to note that no participants rated the selective attention strategy faster than the retrieval strategy. However, those older adults who judged the benefit of retrieval to be less extreme relative to selective attention, chose to use selective attention more often. Thus, even when older adults recognize that retrieval is faster, if they underestimate *how much faster*, they may opt to engage in slower algorithmic processes, instead of the faster retrieval strategy.

Differences in the perceived accuracy of the two strategies relative to the computation strategy was positively correlated with strategy choice particularly for older adults ($p < .001$), but was only marginal for young adults ($p = .064$). Thus, participants were generally more likely to choose the strategy they felt would improve their accuracy more, which was particularly the case for older adults.

Table 6
Correlations Between Differences in Strategy Use and Differences in Metacognitive Ratings for the Choice Condition

	Overall	Young Adults	Older Adults
Confidence	**.56**	**.49**	**.65**
Difficulty	**-.41**	**-.49**	-.32
Accuracy	**.58**	.40	**.72**
Speed	**.41**	.30	**.54**

Note. Bolded correlations are significant at the *p* < .05 level.

Summary of metacognitive influences in the choice condition. Participants typically rated the retrieval strategy more favorably compared to the selective attention strategy. Although older adults typically rated the difference between strategies numerically less extreme compared to younger adults these differences were not reliable. Both young and older adults rated retrieval faster compared to selective attention. Again, participants generally used strategies they were more confident in and found easier to use. Older adults’ strategy use was additionally related to how much faster they felt retrieval was compared to selective attention with those underestimating the RT difference more likely to use selective attention.

CHAPTER IV

DISCUSSION

In the current study, older adults' shift reluctance was restricted to the retrieval strategy. This is in contrast to a general shift reluctance hypothesis which predicts that behavioral inertia from an initial strategy performance decreases strategy shift for older adults regardless of whether or not the task involves a shift to retrieval. Older adults in the selective attention condition readily adopted a non-retrieval-based selective attention strategy to a greater extent than did young. This suggests that behavioral inertia alone is not responsible for older adults' current or previously observed reluctance to shift to retrieval-based strategies (e.g. Touron & Hertzog 2004a; 2004b).

It is possible that the prelearning phase in this study interrupted any inertia built up from Phase 1, leading to an increased likelihood of shifting strategies among older adults. Indeed, pre-learning in this and similar studies (Hines, et al., in press; Touron & Hertzog, 2004a), may introduce some behavioral inertia for the retrieval strategy which increases retrieval strategy adoption. However, these results, like those in previous studies, indicate that older adults essentially shift away from retrieval, back to the computation strategy following prelearning, arguing against a pure inertia account. We argue that top-down, meta-cognitive processes are responsible for older adults' reversions back to less effective strategies following prelearning.

Although the typical finding of older adult retrieval reluctance was found when collapsing across the retrieval and choice conditions, this effect was reduced compared to previous studies. In the current study, older adults used retrieval more often than is typical and young adults used retrieval less often than is typical.

In addition to prelearning having likely increased older adult retrieval use, the current stimuli also differed from those previously used. The current experiment involved learning arbitrary letter pairs, which may have allowed for easier meditational strategy use during study (e.g. using “Burger King” to remember B _ _ _ _ _ [?] K) compared to the more concrete noun-noun combinations (e.g. ivy-bird) used in previous studies (e.g. Touron & Hertzog, 2004a; 2004b). Indeed many older adults spontaneously reported having used a meditational strategy (e.g. story mnemonic, word association, etc…). We did not specifically ask for this information, and thus could not compare rates of meditational strategy use during prelearning between older and younger adults. While meditational strategies used at study may have increased confidence among some participants, the arbitrariness of the letter pairs may have made the task more difficult for others (both young and old). Consistent with this explanation is our finding of considerable variability in ratings of retrieval difficulty and confidence. In previous studies (e.g. Touron & Hertzog, 2004a) young adults are typically more confident to use retrieval and less variable in their confidence compared to older adults’. By contrast young adults were equally variable in their retrieval confidence compared to older adults and there was only a trend towards young being more confident in the retrieval strategy in the current study. This could also in part explain the correlations between young adult confidence and difficulty with retrieval use. Although previous research (e.g. Touron & Hertzog, 2004a; 2004b; 2009) has suggested that mental models are important for determining older adults' strategy use, the current study suggests that mental models may influence young adults' strategy choice on skill acquisition tasks as well—a relationship which may have been masked in previous studies due to a lack of variability in young adult mental models.

An additional reason why retrieval use may have been greater in the current study is that the AVT algorithm was slower and possibly more effortful relative to retrieval compared to previously studied algorithms. For example, in the current study older adults RT benefit for using retrieval was roughly 3000ms, whereas their RT benefit on most noun-pair tasks is typically less than 2000ms (e.g. Touron, 2006; Touron & Hertzog, 2009). Increasing the RT benefit to using retrieval via increasing algorithm RTs has been previously shown to increase older adults shift to retrieval (Touron & Hertzog, 2004b).

Lastly, older adults may have used retrieval more because the computation strategy was less accurate compared to the retrieval strategy in the retrieval condition. This contrasts with previous work in which the algorithm is typically more accurate compared to retrieval (e.g., Touron, 2006). Older adults have been previously shown to be unwilling to trade accuracy for speed (Hertzog et al., 1993), a bias that would typically decrease retrieval use. However when retrieval is more accurate older adults may be more willing to shift away from the less accurate computation strategy. However this same lack of computation accuracy was not found in the choice condition where retrieval use was just as high.

We found relatively low rates of selective attention use among young adults. Aggregate data suggest that young adults in Haider and Frensch's (1996, 1999) samples spontaneously adopted selective attention but strategy was inferred rather than reported, complicating interpretation. Our sample also may have differed from theirs, as only by the last block of training did our young adults in the control condition obtain RTs (*M* = 4826, *SE* = 369) as fast as those on their first block of training (means between 4000 and 5000ms). However this may be the result of stimuli being spaced farther apart in the current study for eye-tracking purposes. It is unclear to what extent this may impact RTs (Haider and Frensch do not report RTs for their 1999 eye-tracking experiment) or whether overall performance speed relates to strategy use. Also, because Haider & Frensch (1996, 1999) used repeated stimuli, young adults in their studies may have been shifting to retrieval as well as or instead of selective attention, causing them to both overestimate selective attention adoption and the selective attention RT benefits in their studies.

One explanation as to why our young adults may have avoided the selective attention strategy is that they may not have believed that the errors would truly occur only in the triplet region. However, we dropped participants who responded (on the PTQ) that they used the computation strategy due to mistrusting the instructions, so our low rate of selective attention use among young cannot be explained by suspected deception. In contrast, the metacognitive data suggest that young adults sometimes relied on computation because they were not confident in their ability to successfully employ the selective attention strategy or they felt the selective attention strategy actually made the task more difficult. Whether young adults believed that selective attention would improve their performance speed was not related to selective attention use or actual RT improvements from using selective attention. Therefore the current sample of young adults seemed unwilling to use a strategy that they felt was more difficult or in which they lacked confidence, regardless of whether or not they felt that the strategy would have been faster had they used it. It seems counterintuitive that the selective attention strategy would be difficult and that young adult would have low confidence in their selective attention ability; perhaps young adult recognized that the run-up from the non-triplet region was difficult to inhibit and beneficial to performance. In contrast to young, older adults readily switched to the selective attention strategy, even more so when they believed the selective attention strategy to be faster and less difficult.

Older adults also might have engaged in more selective attention use because they showed larger RT benefits for the selective attention strategy compared to young adults. However, the causal direction of such an effect cannot be disentangled; older adults' greater RT improvements could be the result of their greater selective attention use. Because the primary goal of the study was to assess strategy choice, the design did not require participants to use each strategy an equal number of times. As a result the RT estimates should be taken with some degree of caution as individual differences in processing speed could be confounded with individual differences in strategy choice. For example, faster participants may have been more or less likely to shift strategies, in which case the benefit of a strategy might be over or underestimated. In the control condition where participants were forced to use computation on every trial they were no slower compared to those choosing to use selective attention regularly in the selective attention and choice conditions. But even this finding must be interpreted with caution as control condition participants did not have the added task of monitoring strategy use, which may have increased RTs among selective attention and choice participants. These concerns aside, strategy benefits alone cannot explain why older adults would differentially use strategies as the retrieval strategy proved far more beneficial compared to the selective attention strategy for both older and younger adults. Many older adults were reluctant to use a highly beneficial retrieval strategy while showing no reluctance to use a modestly beneficial selective attention strategy.

Despite the popularity of the selective attention strategy among older adults in the selective attention condition, older adults typically chose the retrieval strategy over selective attention in the choice condition. However, choosing retrieval over selective attention was related to whether older adults felt more confident in the retrieval strategy versus the selective attention strategy, and whether they found the retrieval strategy to be substantially faster compared to the selective attention strategy. Although no participant in the current study believed the selective attention strategy was faster than the retrieval strategy, older adults varied in how much faster they felt retrieval was (whereas young adults nearly universally gave retrieval the highest speed rating). Even though they knew retrieval was the faster strategy, older adults remained reluctant to use it if they believed it was only minimally faster. This suggests that older adults are particularly avoidant to using retrieval-based strategies unless sufficiently confident and/or motivated by performance benefits (see Touron et al., 2007 for how monetary incentives can achieve this same motivational effect). This is consistent with previous findings suggesting that a RT monitoring deficit contributes to older adults' reluctance to use retrieval-based strategies (Hertzog et al., 2007).

In addition to perceived performance benefits, both older and younger adults' retrieval use was related to confidence in their ability to use the retrieval strategy as well as difficulty of the retrieval strategy. This is consistent with previous research which shows that task-specific memory confidence and retrieval difficulty correlate with older adults' retrieval use (e.g. Touron & Hertzog, 2004a; 2004b; 2009).

Aside from the primary research question, the current experiment was also novel in the use of strategy reports with a selective attention strategy. This is the first study to our knowledge to use strategy reports concurrent or otherwise with a selective attention strategy. It was previously unknown as to whether young let alone older adults could reliably monitor and report selective attention. Selective attention reports as well as those for the retrieval and computation strategies appeared to be generally valid, with RT and gaze data converging on similar conclusions. Computation reports were associated with an increase in both RT and non-triplet gazes for longer strings. Retrieval reports were associated with faster RTs and fewer gazes overall. Selective attention reports were associated with smaller increases in RT and gaze counts for longer strings. The expected pattern of RTs was not found for computation or selective attention only with conditions in which those strategies were infrequent, likely reflecting unstable RT estimates as opposed to invalid strategy reports.

In summary, older adults’ shift reluctance does not appear to generalize to all strategies, and may be retrieval specific. That is, older adults are not compelled by a behavioral inertia to inflexibly perform tasks the way they had previously learned to do them. Instead, the current data suggest that older adults readily adopt non-retrieval-based strategies to reduce task difficulty and improve performance. However, the current study examines strategy shift to only one possible alternative strategy. It may be the case that older adults are particularly willing to shift to selective attention or other “step-skipping” strategies. We do not argue that retrieval is the only strategy for which older adults may be under-confident, find more difficult, or fail to see the benefits; older adults may well be shift avoidant to other strategies (as may young adults). Future research should consider shift-reluctance in other non-retrieval skill acquisition tasks. Future research should also consider manipulating the cost-benefit ratio of selective attention shift to examine whether young adults might adopt the strategy more if it were more beneficial or if older adults might adopt it less if it were less beneficial.

Previous work has suggested that appropriate incentives (Touron et al., 2007) or conditions in which retrieval is more beneficial relative to algorithmic processes (Touron & Hertzog, 2004b) may improve older adults’ performance by encouraging them to use retrieval-based strategies. The current research suggests that an alternative way to improve older adults’ performance, albeit to a lesser extent, may be to identify more efficient algorithmic processes which older adults may be more willing to adopt. Likewise, because older adults do indeed learn associations more slowly compared to young adults (Hoyer, et al., 2003; Touron, Hoyer, & Cerella, 2001; 2004), it may be the case that selective attention strategies could (and may) be employed earlier by older adults before learning has allowed them to use retrieval-based strategies. Future research should examine selective attention strategy discovery rates among older adults to help identify to what extent older adults may be capable of employing selective attention strategies in real world settings without the aid of instructions which explicitly detail such strategies.

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FOOTNOTES

1. Data were excluded from analysis if a participant achieved less than 70% accuracy overall on the task; this resulted in the loss of five young adults: one in the control condition, one in the retrieval condition and two in the SA condition. Two YAs and one OA in the retrieval condition, and one OA in the SA condition were dropped because they indicated that they did not fully understand the response options. Participant data was also excluded from analysis if they indicated on a post-task questionnaire that they suspected deception and avoided using the SA strategy as a result (seven YAs and one OA in the SA condition, and six YAs and one OA in the choice condition). Two more OAs' data were excluded for poor visual acuity, and a computer error. One YA in the SA and one YA in the choice condition were excluded due to median Phase 1 RTs more than two standard deviations above the young adult mean. Two YAs in the retrieval condition were excluded because they rarely used the retrieval strategy and endorsed beliefs about the retrieval strategy inconsistent with those of their peers. It is unknown whether these individuals are merely outliers or represent a sub-group of YAs. No similar subgroup of YAs has been seen in previous strategy shift research, nor did they exist in our choice condition.
2. Triplet deviations were of two types, either the last letter was one letter further in the alphabet than the correct letter would be (e.g., G [4] M), or the last letter was the letter preceding the correct letter (e.g., G [4] K). Non-triplet deviations preceded the triplet, and either skipped a letter (e.g., B D E F G [4] L), or began

partially with some (e.g., H I J F G [4] L) or exclusively with only (e.g., H I J K G [4] L) letters contained in the triplet. All letters in the false strings were thus from the same portion of the alphabet to avoid automatic responding based on anomalous appearance.

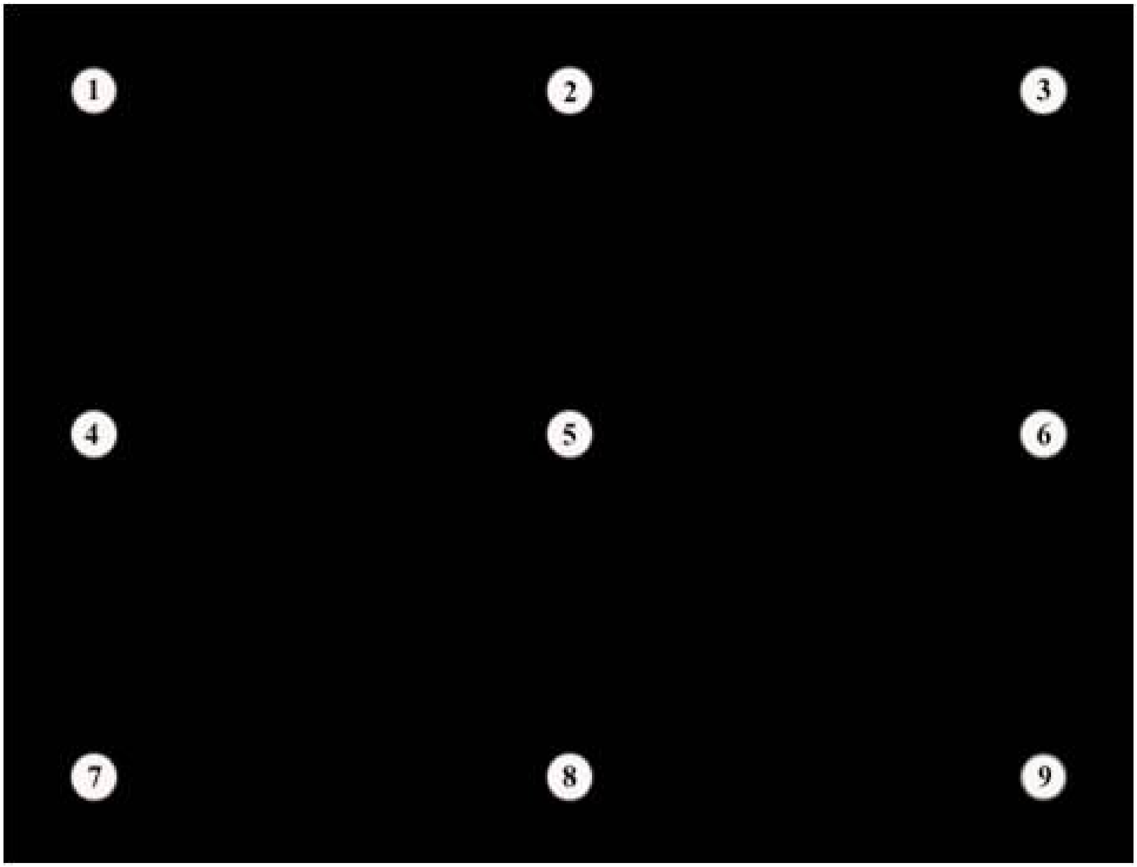
3. For the retrieval condition the options ‘c’ for compute, ‘m’ for memory, and ‘o’ for other re-labeled the ‘z,’ ‘x,’ and ‘c’ keys on the keyboard, respectively. In the SA condition options ‘f’ for full compute, ‘t’ for triplet, and ‘o’ for other re-labeled the ‘z,’ ‘x,’ and ‘c’ keys on the keyboard, respectively. In the choice condition the options ‘f’ for full compute, ‘m’ for memory, ‘t’ for triplet, and ‘o’ for other re-labeled the ‘z,’ ‘x,’ ‘c,’ and ‘v’ keys on the keyboard, respectively but with the order of ‘m’ and ‘t’ counterbalanced.
4. For the purpose of determining the percentage of gazes occurring outside the areas of interests we also included an AOI around the question appearing below the letter string. However, gazes to the question were excluded prior to the following analyses.
5. It is typical in eye tracking studies to lose around 10% and 30% of tracking data for younger and older adults, respectively. Technician notes indicate that the high data loss for YAs was often the result of YAs being more likely to partially close their eyes while computing the triplet portion of the string.
6. Results were equivalent when string length was included in the model; no main effects or interactions with string length.

7. RTs for +1strings did not differ from triplet only or +2 strings, (*p*s > .170). However, strings of +2 were reliably longer than +0 strings, *t*(164) 2.13, *p* = .035, *d* = 0.10. From length +2 to +4 RTs increased reliably and incrementally (*p*s < .040, *d*s > 0.13).
8. Selective attention use decreased from Block 1 to Block 2, *t*(41) = 2.46, *p* = .018, *d* = 0.26, but did not decrease thereafter (all other *p*s > .190). Retrieval use increased from Block 1 to Block 2, *t*(41) = 4.37, *p* < .001, *d* = 0.32, and from Block 4 to Block 5, *t*(41) = 2.05, *p* = .047, *d* = 0.07. Retrieval use did not increase reliably from Blocks 2 through 4 or Block 5 to 6 (all *p*s > .078).
9. Computation use decreased from Block 1 to Block 2, *t*(41) = 2.05, *p* = .046, *d* = 0.16, but did not decrease thereafter (all other *p*s > .170).
10. Retrieval use increased between Blocks 1 and 2, *t*(80) = 3.81, *p* < .001, *d* = 0.22, and Blocks 4 and 5 *t*(80) = 2.01, *p* = .047, *d* = 0.05. Retrieval use did not reliably increase from Block 2 to 4 (all *p*s > .085), or from Block 5 to 6 (*p* = .692).
11. Although there was not a reliable increase in RT from string lengths +0 to +2 for computation, *t*(29) = 0.20, *p* = .840, there was a reliable increase in RT from length +2 to +4, *t*(29) = 3.66, *p* = .001, *d* = 0.39, and +0 to +4, *t*(29) = 3.39, *p* = .002, *d* = 0.32. There were no reliable differences in RT by string length for the selective attention strategy (all *p*s > .180).
12. We also examined whether participant's ratings of efficiency benefits were related to how much they actually benefitted from that strategy (in terms of RT). To do this, we subtracted each participant's overall median SA/retrieval RT from their

overall median computation RT. We then examined for each condition, and each age X condition cell, whether these differences correlate with the ratings of performance speed benefits. Perceived benefit of retrieval was not correlated with the actual benefit for either YAs (r = -.28, p = .314) or OAs (r = .39, p = .121). Perceived benefit of the SA strategy was correlated with the actual benefit for OAs (r = .50, p = .041) but not YAs (r = .09, p = .715). However the reliable correlation among OAs was driven by two participants with negative benefits for SA. With these participants removed the correlation was no longer reliable (r = .30, p = .270). It does not appear that participants were generally able to construct an accurate mental model of relative strategy efficiency, although given power concerns this interpretation is extremely tentative.

APPENDIX A

CALIBRATION SCREEN



APPENDIX B

PHASE 1 INSTRUCTIONS

Phase 1 instructions

Welcome.
Thank you for participating in this experiment for the Adult Cognition Lab.

Computer Instructions

Most of the time you spend in this experiment will involve working on the computer. The computer will offer you frequent breaks. If needed, you can use these breaks to relax your mind and your typing fingers. If necessary, you may get up for a more extended break, but realize that we will have to re-calibrate the eye-tracker when you return. If you have a question or must leave the room for a break, please do so only when the breaks are provided. When you have finished, the computer will ask you to get the experimenter.

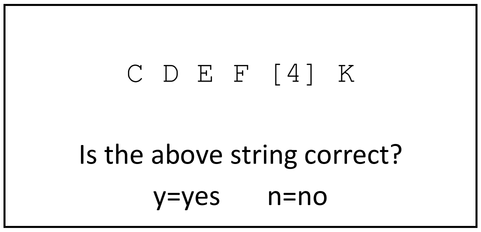
You will answer different types of questions on the computer. The rest of your instructions will describe these question types. Following the instructions, you will take a short comprehension quiz. ***Read the instructions carefully***, as you cannot proceed to testing until you correctly respond to all of the comprehension questions.

PLEASE PRESS ENTER TO CONTINUE.

Phase 1 instructions continued

When your testing begins, you will be asked to verify whether letter strings are in correct alphabetical order. Each letter string includes both letters and a number in brackets. The number in brackets represents the number of letters between the letter before and the letter after the brackets.

Look at this example:



C D E F [4] K

Is the above string correct?

y=yes n=no

In the example, C D E F [4] K, the [4] represents the four letters [G, H, I, and J] that fall between F and K. Therefore the string C D E F [4] K is alphabetically correct.

PLEASE PRESS ENTER TO CONTINUE.

Phase 1 instructions continued

Look at this example:

C D E G [4] L

Is the above string correct?

y=yes n=no

The string C D E G [4] L is alphabetically incorrect because the letter F should follow the letter E, but G is shown instead.

PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 1 instructions continued

Look at this example:

C D E F [4] L

Is the above string correct?
y=yes n=no

In this example, the string C D E F [4] L is alphabetically incorrect because F [4] represents F followed by the next 4 letters [G, H, I, J], so the next letter should be K rather than L.

PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 1 instructions continued

With your right hand you will press the keys marked “Y” and “N” to respond. If the letter string is alphabetically correct respond YES, “Y,” with the index finger of your right hand. If the letter string is alphabetically incorrect respond NO, “N,” with the middle finger of your right hand. You should keep your fingers resting on these keys at all times, so that your response is not slowed by looking down at the keyboard and moving your hands. We measure how long it takes for you to respond to these strings, as well as how accurate you are. Therefore you should try to be both fast and accurate.

PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 1 instructions continued

Before each string, you will see a mark in the center of the screen. This mark shows you where to focus your eyes. Since we measure response times, it is important that you be looking at the question when it first appears on the screen.

Before each string you will see:

+

PLEASE PRESS ENTER TO BEGIN THE TASK OR BACKSPACE TO REVIEW.

APPENDIX C

PHASE 1 QUIZ

To be completed by Experimenter:
Participant #: ________
Date: ____/____/____
Condition:

Phase 1 Instruction Quiz

1) In the following sequence, what letter should come next?

A B C D E [5] __

Please circle the letter that is alphabetically <u>incorrect</u> for each of the following strings:
2) H [5] N
3) B D E F G [4] L
4) G H I [5] P
5) N M [4] R

APPENDIX D

STIMULI

<u>True Strings</u>

F G H I J [4] O
C D E F G [4] L
P Q R S T [4] Y
H I J K L [4] Q
L M N O P [5] V
F G H I J [5] P
C D E F G [5] M
J K L M [4] R
D E F G [4] L
B C D E [4] J
C D E F [4] K
B C D E [5] K
E F G H [5] N
H I J K [5] Q
A B C D [5] J
G H I J [5] P
A B C [4] H
P Q R [4] W
R S T [4] Y
O P Q [4] V
O P Q [5] W
M N O [5] U
L M N [5] T
P Q R [5] X
M N O [4] T
K L [4] Q
R S [4] X
M N [4] S
L M [4] R
K L [5] R
R S [5] Y
C D [5] J
L M [5] S
M N [5] T
Q [4] V
S [4] X
I [4] N
H G [5] M
G F [5] L
F G [4] M
O P [4] T
H I [4] M
Q R [5] Y
D E [5] L
H [4] N
A [4] G
N [4] T
J [4] P
D [4] H
H [5] O
H [4] M
E [5] K
P [5] V
N [5] T
F [5] L
R [4] W

False Strings

A C D E F [4] K
N J K L M [5] S
G H D E F [4] K
J K M N O [5] U
L M N P Q [5] W
O P Q M N [5] T
D E F G I [4] N
P Q R S O [5] U
P Q R S T [4] X
A B C D E [5] J
N P Q R [4] W
J L M N [5] T
B C E F [4] K
K L I J [4] O
O P M N [5] T
B C D F [4] K
I J K M [5] S
B C D E [4] K
A B C D [5] I
L J K [4] P
I K L [5] R
D F G [5] M
U V T [4] Y
T U S [5] Y
Q R P [5] V
J K L [4] R
D E F [4] J
L M N [5] U
H J [4] O
M O [4] T
H G [5] M
G F [5] L
F G [4] M
O P [4] T
H I [4] M
Q R [5] Y
D E [5] L
H [4] N
A [4] G
N [4] T
J [4] P
D [4] H
H [5] O
O [5] V
J [5] Q
N [5] U
F [5] K

APPENDIX E

PHASE 2 INSTRUCTIONS

PHASE 2

In the next part of the experiment, you will verify 6 strings similar to the ones you computed in Phase 1.

However, we will now ask that you memorize the first and last letters from the strings for a memory test that will follow. The strings will be provided on the next screen.

On the memory test, we will show you the first and last letters of the memorized strings without the intervening letters or bracketed number and ask you to verify whether a string is a correct string from the list or is not a correct string from the list. We do this so that you can't compute the strings but must use memory instead.

Look at this example:

B _ _ _ _ [?] K

Is the above string correct?

y=yes n=no

PRESS ENTER TO CONTINUE.

You will now memorize the 6 strings below.

It is important to note that you only need to memorize the first and last letter of each string in order to use your memory for the next test. We also show you the full strings below, but you *do not* need to memorize the letters between the first and last or the bracketed number.

For example you should memorize that B and K go together, so that when you see B _ _ _ _ [?] K you'll know to respond 'yes' using memory.

Correct Strings	How they will appear at test
B C D E F [4] K	B _ _ _ _ [?] K
D E F G H [5] N	D _ _ _ _ [?] N
F G H [4] M	F _ _ [?] M
H I J [5] P	H _ _ [?] P
G [4] L	G [?] L
I [5] O	I [?] O

PLEASE STUDY THE FIRST AND LAST LETTERS OF THE ABOVE STRINGS.

WHEN YOU HAVE THE INFORMATION MEMORIZED, PLEASE PRESS ENTER TO BEGIN THE TEST OR PRESS BACKSPACE TO REVIEW.

APPENDIX F

PHASE 2 TEST EXAMPLE

D _ _ _ _ [?] N

Is the above string correct?

y=yes n=no

APPENDIX G

PHASE 3 INSTRUCTIONS

Phase 3 control condition instructions

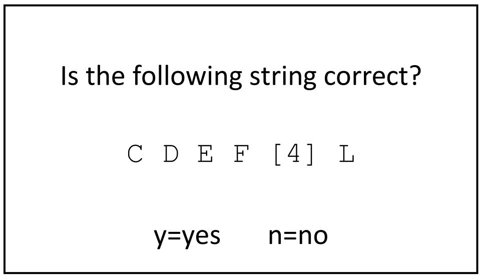
Phase 3

In Phase 1 you had to compute both the ‘triplet’ and ‘non-triplet’ portions of the strings. For the next task you will again verify the alphabetical correctness of letter strings using this strategy.

PLEASE PRESS ENTER TO CONTINUE.

Phase 3 control condition instructions continued

Look at this example:



Is the following string correct?

C D E F [4] L

y=yes n=no

In the example, C D E F [4] L, is incorrect because K rather than L should follow the [4]. Thus you would press ‘N’ for ‘no.’

Note that the strings you memorized in Phase 2 will **NOT** be used in the next task. Therefore, you must compute the entire string to tell if the strings are alphabetically correct.

PLEASE RAISE YOUR HAND AND THE EXPERIMENTER WILL GIVE YOU AN INSTRUCTION QUIZ OR PRESS BACKSPACE TO REVIEW.

Phase 3 retrieval condition instructions

PHASE 3

In Phase 1 you had only one strategy for solving the strings available. You had to compute both the ‘triplet’ and ‘non-triplet’ portions of the strings. We call this the ‘**COMPUTE**’ strategy, because you computed the string.

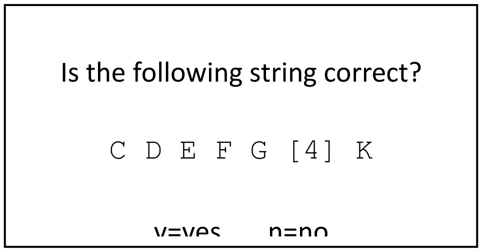
For the next task you will again verify the alphabetical correctness of letter strings, but now you will have **two** strategies to choose from to verify the letter strings: The ‘**COMPUTE**’ strategy which you used in Phase 1 and the ‘**MEMORY**’ strategy, which will be explained next.

PLEASE PRESS ENTER TO CONTINUE.

Phase 3 retrieval condition instructions continued

Memory Strategy

Look at this example:



Is the following string correct?

C D E F G [4] K

y=yes n=no

In the next task errors may again occur in either the ‘triplet’ (G [4] K) or ‘non-triplet’ (C D E F) portion of the string, however all the alphabetically correct strings will be those you memorized in Phase 2. Thus you can use your memory to verify the strings.

In this example the C D E F G [4] K is incorrect because L rather than K should follow the [4]. Thus you would press ‘N’ for ‘no.’

You could also determine that this string is incorrect because C _ _ _ _ [?] K was NOT one of the strings you memorized. We call this the ‘**MEMORY**’ strategy.

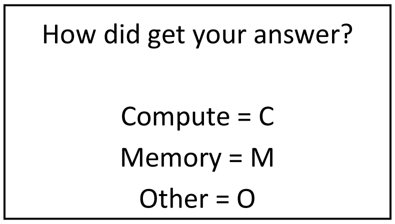
In the following task you will have the option to use the ‘**COMPUTE**’ strategy or use the ‘**MEMORY**’ strategy as either strategy will allow you to verify the alphabetical correctness of the strings.

PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 3 retrieval condition instructions continued

Response Strategy Questions

Following each string verification response, you will be asked whether you computed the entire string or used memory.



How did get your answer?

Compute = C
Memory = M
Other = O

With your left hand, you will press the keys marked '**C****,' '****M****' and '****O****' to respond.** If you computed the entire string, respond **COMPUTE**, '**C**.' If you used your memory, respond **MEMORY**, '**M**.' If you don't know how you got the answer, respond **OTHER**, '**O**.' These strategy questions are not timed. It is more important that you respond accurately than quickly on the strategy response questions.

PLEASE RAISE YOUR HAND AND THE EXPERIMENTER WILL GIVE YOU AN INSTRUCTION QUIZ OR PRESS BACKSPACE TO REVIEW.

Phase 3 SA condition instructions

PHASE 3

In Phase 1 you had only one strategy for solving the strings available. You had to compute both the ‘triplet’ and ‘non-triplet’ portions of the strings. We call this the ‘**FULL COMPUTE**’ strategy, because you computed the full string.

For the next task you will again verify the alphabetical correctness of letter strings, but now you will have **two** strategies to choose from to verify the letter strings: The ‘**FULL COMPUTE**’ strategy which you used in Phase 1 and the ‘**TRIPLET**’ strategy, which will be explained next.

Note that the strings you memorized in Phase 2 will **NOT** be used in the next task. Therefore you must compute the entire string or use the triplet strategy to tell if the strings are alphabetically correct.

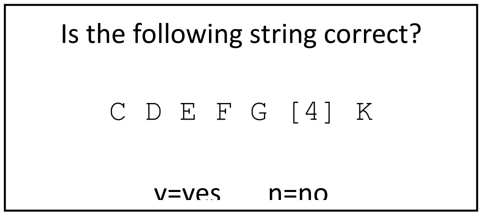
PLEASE PRESS ENTER TO CONTINUE.

Phase 3 SA condition instructions continued

Triplet Strategy

In the next task alphabetical deviations will now occur **<u>only</u>** in the ‘triplet.’

Look at this example:



Is the following string correct?

C D E F G [4] K

y=yes n=no

In this example the triplet G [4] K is incorrect because L rather than K should follow the [4]. Thus you would press ‘N’ for ‘no.’

In the next task you may choose to only look at the triplet (e.g. G [4] K), as the non-triplet portion (e.g. C D E F) will always be correct. We call this the ‘**TRIPLET**’ strategy.

In the following task you will have the option to use the ‘**FULL COMPUTE**’ strategy or use the ‘**TRIPLET**’ strategy as either strategy will allow you to verify the alphabetical correctness of the strings.

PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 3 SA condition instructions continued

Response Strategy Questions

Following each string verification response, you will be asked whether you computed the entire string, or computed just the triplet.

How did get your answer?

Full Compute = F
Triplet = T
Other = O

With your left hand, you will press the keys marked 'F,' 'T' and 'O' to respond. If you computed the entire string, respond **FULL COMPUTE**, '**F**.' If you compute only the triplet, respond **TRIPLET**, '**T**.' If you don't know how you got the answer, respond **OTHER**, '**O**.' These strategy questions are not timed. It is more important that you respond accurately than quickly on the strategy response questions.

Note that there is no difference between the **FULL COMPUTE** and **TRIPLET** strategies for strings that do not contain a non-triplet portion (e.g. A [4] F). For these 'triplet only strings' you may respond either '**F**,' or '**T**,' if you compute the string.

PLEASE RAISE YOUR HAND AND THE EXPERIMENTER WILL GIVE YOU AN INSTRUCTION QUIZ OR PRESS BACKSPACE TO REVIEW.

Phase 3 choice condition instructions

PHASE 3

In Phase 1 you had only one strategy for solving the strings available. You had to compute both the ‘triplet’ and ‘non-triplet’ portions of the strings. We call this the ‘**FULL COMPUTE**’ strategy, because you computed the full string.

For the next task you will again verify the alphabetical correctness of letter strings, but now you will have **three** strategies to choose from to verify the letter strings: The ‘**FULL COMPUTE**’ strategy which you used in Phase 1, and the ‘**MEMORY**’ and ‘**TRIPLET**’ strategies which will be explained next.

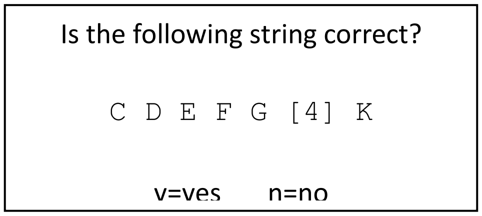
PLEASE PRESS ENTER TO CONTINUE.

Phase 3 choice condition instructions continued

Memory Strategy

In the next task all the alphabetically correct strings will be those you memorized in Phase 2. Thus you can use your memory to verify the strings.

Look at this example:



Is the following string correct?

C D E F G [4] K

y=yes n=no

You could determine that this string is incorrect because C _ _ _ _ [?] K was NOT one of the strings you memorized. We call this the '**MEMORY**' strategy.

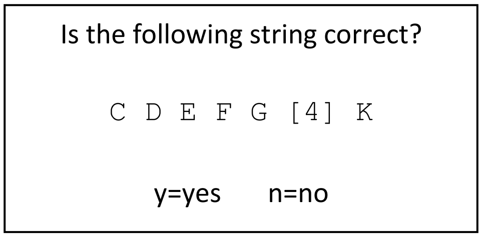
PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 3 choice condition instructions continued

Triplet Strategy

In addition to all the alphabetically correct strings being those you memorized in Phase 2, alphabetical deviations will now occur **<u>only</u>** in the 'triplet.'

Look at this example:



Is the following string correct?

C D E F G [4] K

y=yes n=no

In this example the triplet G [4] K is incorrect because L rather than K should follow the [4]. Thus you would press 'N' for 'no.' In the next task you may choose to only look at the triplet (e.g. G [4] K), as the non-triplet portion (e.g. C D E F) will always be correct. We call this the '**TRIPLET**' strategy.

In the following task you will have the option to use the '**FULL COMPUTE**' strategy, use the '**MEMORY**' strategy or use the '**TRIPLET**' strategy as any of these strategies will allow you to verify the alphabetical correctness of the strings.

PLEASE PRESS ENTER TO CONTINUE OR BACKSPACE TO REVIEW.

Phase 3 choice condition instructions continued

Response Strategy Questions

Following each string verification response, you will be asked whether you computed the entire string, used memory, or computed just the triplet.

How did get your answer?
Full Compute = F
Memory = M
Triplet = T
Other = O

With your left hand, you will press the keys marked 'F,' 'M,' 'T' and 'O' to respond. If you computed the entire string, respond **FULL COMPUTE**, '**F**.' If you used your memory, respond **MEMORY**, '**M**.' ' If you compute only the triplet, respond **TRIPLET**, '**T**.' If you don't know how you got the answer, respond **OTHER**, '**O**.' These strategy questions are not timed. It is more important that you respond accurately than quickly on the strategy response questions.

Note that there is no difference between the **FULL COMPUTE** and **TRIPLET** strategies for strings that do not contain a non-triplet portion (e.g. A [4] F). For these 'triplet only strings' you may respond either '**F**,' or '**T**,' if you compute the string

PLEASE RAISE YOUR HAND AND THE EXPERIMENTER WILL GIVE YOU AN INSTRUCTION QUIZ OR PRESS BACKSPACE TO REVIEW.

APPENDIX H

PHASE 3 QUIZZES

Phase 3 control condition instruction quiz

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition: 1

Instruction Quiz

Please circle the correct response.

1) I **can/cannot** use my memory for the letter strings I just studied on the next task.

2) Please circle the portion(s) in the following string in which errors **could** occur on the next task (circle all that apply):
H I J K [5] Q
Note that this string is correct, we are only asking where an error **could** occur if one were present.

Phase 3 retrieval condition instruction quiz

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition: 2

Instruction Quiz

Please circle the correct response.

3) I **can**/**cannot** use my memory for the letter strings I just studied on the next task.

4) Please circle the portion(s) in the following string in which errors **could** occur on the next task (circle all that apply):
   H I J K [5] Q
   Note that this string is correct, we are only asking where an error **could** occur if one were present.

5) Circle the portion(s) of the following string that would be checked if you were to use the **Compute** strategy:
   J K L M [5] S

6) Circle the portion(s) of the following string that would be checked if you were to use the **Memory** strategy:
   L M N O [5] U

Phase 3 SA condition instruction quiz

To be completed by Experimenter:
Participant #: ________
Date: ____/____/____
Condition: 3

Instruction Quiz

Please circle the correct response.

7) I **can**/**cannot** use my memory for the letter strings I just studied on the next task.

8) Please circle the portion(s) in the following string in which errors **could** occur on the next task (circle all that apply):

H I J K [5] Q

Note that this string is correct, we are only asking where an error **could** occur if one were present.

9) Circle the portion(s) of the following string that would be checked if you were to use the **Full Compute** strategy:

J K L M [5] S

10) Circle the portion(s) of the following string that would be checked if you were to use the **Triplet** strategy:

I J K L [5] R

Phase 3 choice condition instruction quiz

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition: 4

Instruction Quiz

Please circle the correct response.

11) I **can**/**cannot** use my memory for the letter strings I just studied on the next task.

12) Please circle the portion(s) in the following string in which errors **could** occur on the next task (circle all that apply):
    H I J K [5] Q
    Note that this string is correct, we are only asking where an error **could** occur if one were present.

13) Circle the portion(s) of the following string that would be checked if you were to use the **Full Compute** strategy:
    J K L M [5] S

14) Circle the portion(s) of the following string that would be checked if you were to use the **Triplet** strategy:
    I J K L [5] R

15) Circle the portion(s) of the following string that would be checked if you were to use the **Memory** strategy:
    L M N O [5] U

APPENDIX I

PHASE 3 TRUE STIMULI CONTROL AND SELECTIVE ATTENTION CONDITIONS

D E F G H [4] M
J K L M N [4] S
E F G H I [4] N
G H I J K [4] P
I J K L M [4] R
O P Q R S [4] X
L M N O P [4] U
M N O P Q [4] V
A B C D E [4] J
N O P Q R [4] W
K L M N O [4] T
Q R S T U [4] Z
N O P Q R [5] X
I J K L M [5] S
G H I J K [5] Q
O P Q R S [5] Y
H I J K L [5] R
E F G H I [5] O
J K L M N [5] T
A B C D E [5] K
M N O P Q [5] W
K L M N O [5] U
B C D E F [5] L
P Q R S T [5] Z
L M N [4] S
B C D [4] I
N O P [4] U
G H I [4] N
E F G [4] L
J K L [4] Q
Q R S [4] X
I J K [4] P
C D E [4] J
D E F [4] K
H I J [4] O
K L M [4] R
G H I [5] O
A B C [5] I
F G H [5] N
E F G [5] M
I J K [5] Q
C D E [5] K
B C D [5] J
N O P [5] V
K L M [5] S
Q R S [5] Y
J K L [5] R
D E F [5] L
P [4] U
C [4] H
T [4] Y
N [4] S
A [4] F
F [4] K
J [4] O
E [4] J
M [4] R
B [4] G
D [4] I
K [4] P
O [5] U
R [5] X
B [5] H
M [5] S

S [5] Y
C [5] I
D [5] J
Q [5] W
G [5] M
H [5] N
K [5] Q
L [5] R

APPENDIX J

PHASE 3 FALSE STIMULI CONTROL CONDITION

M I J K L [4] Q
E G H I J [4] O
N P Q R S [5] Y
G C D E F [5] L
O P L M N [4] S
U V R S T [4] Y
H I K L M [4] R
L M I J K [5] Q
S T P Q R [5] X
O P L M N [5] T
K L M I J [4] O
T U V R S [4] X
S T U Q R [5] X
A B C E F [5] L
F G H I K [4] P
J K L M I [4] N
L M N O Q [4] V
S T U V R [5] X
C D E F H [5] N
H I J K G [5] M
E F G H I [4] P
I J K L M [4] Q
F G H I J [5] O
L M N O P [5] X
E G H [4] M
E C D [4] I
D F G [4] L
G E F [4] K
G I J [5] P
N L M [5] S
J L M [5] S
P N O [5] U
Q R P [4] U

J K I [4] N
D E G [4] L
N O M [4] R
O P R [5] X
M N P [5] V
N O Q [5] W
J K I [5] O
Q R S [4] W
C D E [4] K
O P Q [4] W
K L M [4] Q
D E F [5] K
C D E [5] J
M N O [5] V
J K L [5] S
O [4] U
B [4] F
L [4] R
Q [4] W
M [4] S
Q [4] U
K [4] Q
R [4] V
J [4] N
T [4] X
C [4] I
D [4] J
M [5] R
F [5] M
E [5] L
H [5] M
D [5] K
P [5] U

Q [5] X
A [5] F
R [5] Y
Q [5] V
K [5] P
T [5] W

APPENDIX K

PHASE 3 FALSE STIMULI SELECTIVE ATTENTION CONDITION

E F G H I [4] P
I J K L M [4] Q
M N O P Q [4] U
H I J K L [4] S
F G H I J [4] Q
L M N O P [4] T
G H I J K [4] R
E F G H I [4] M
J K L M N [4] R
A B C D E [4] I
C D E F G [4] N
L M N O P [4] W
F G H I J [5] O
L M N O P [5] X
A B C D E [5] M
O P Q R S [5] X
L M N O P [5] U
E F G H I [5] N
J K L M N [5] V
H I J K L [5] Q
K L M N O [5] Y
E F G H I [5] Q
I J K L M [5] R
C D E F G [5] O
Q R S [4] W
C D E [4] K
O P Q [4] W
K L M [4] Q
B C D [4] J
Q R S [4] Y
A B C [4] G
J K L [4] P
K L M [4] S
R S T [4] X
I J K [4] O
G H I [4] M
D E F [5] K
C D E [5] J
M N O [5] V
J K L [5] S
P Q R [5] Y
B C D [5] K
N O P [5] U
J K L [5] Q
M N O [5] T
E F G [5] N
L M N [5] S
E F G [5] L
O [4] U
B [4] F
L [4] R
Q [4] W
M [4] S
Q [4] U
K [4] Q
R [4] V
J [4] N
T [4] X
C [4] I
D [4] J
M [5] R
E [5] L
H [5] M
D [5] K
P [5] U
Q [5] X

A [5] F
R [5] Y
Q [5] V
K [5] P
T [5] W
F [5] M

APPENDIX L

PHASE 3 TRUE AND FALSE STIMULI RETRIEVAL CONDITION

True	False
B C D E F [4] K	B C D E F [4] M
	B C D E F [5] N
	B D E F G [4] L
	B D E F G [5] M
	B C E F G [4] L
	B C E F G [5] M
	B C D F G [4] L
	B C D F G [5] M
	B C D E G [4] L
	B C D E G [5] M

True	False
D E F G H [5] N	D E F G H [4] O
	D E F G H [5] P
	D E F G H [4] L
	D E F G H [5] M
	D F G H I [5] O
	D E G H I [5] O
	D E F H I [5] O
	D E F G I [5] O

True	False
F G H [4] M	F G H [4] N
	F G H [5] O
	F G H [4] L
	F H I [4] N
	F H I [5] O
	F G I [4] N
	F G I [5] O
	F G E [4] J
	F G E [5] K
	F D E [4] J
	F D E [5] K

True	False

H I J [5] P	H I J [4] N
	H I J [5] O
	H I G [4] L
	H I G [5] M
	H F G [4] L
	H F G [5] M
True	False

G [4] L	G [4] M
	G [5] N
	G [4] K
True	False

I [5] O	I [5] P
	I [4] M
	I [5] N

APPENDIX M

PHASE 3 TRUE AND FALSE STIMULI CHOICE CONDITION

True	False
B C D E F [4] K	B C D E F [4] M B C D E F [5] N

True	False
D E F G H [5] N	D E F G H [4] O D E F G H [5] P D E F G H [4] L D E F G H [5] M

True	False
F G H [4] M	F G H [4] N F G H [5] O F G H [4] L

True	False
H I J [5] P	H I J [4] N H I J [5] O

True	False
G [4] L	G [4] M G [5] N G [4] K

True	False
I [5] O	I [5] P I [4] M I [5] N

APPENDIX N

PTQS

Control Condition PTQ

POST-TESTING QUESTIONNAIRE

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition:

PART ONE: **In the first part of the computer task, you COMPUTED AND VERIFIED letter strings. Please answer the following questions about this part of the computer task.**

1) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART TWO: **In the second part of the computer task, you STUDIED AND WERE TESTED ON 6 letter strings. Please answer the following questions about the study-test portion of the computer task.**

2) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART THREE: **In the third part of the computer task, you again COMPUTED AND VERIFIED letter strings. Please answer the following questions about this part of the computer task.**

3) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

HOW CONFIDENT ARE YOU THAT YOU CAN RECALL THE LAST LETTER OF THE CORRECT LETTER STRINGS FROM PHASE 2 WHEN PROMPTED WITH THE FIRST LETTER AND LIST LENGTH?

Please **circle** your confidence rating for each pair below.

0= won't recall **100= definitely will recall**

B_ _ _ _ _ [?] ?	0	10	20	30	40	50	60	70	80	90	100
D_ _ _ _ _ [?] ?	0	10	20	30	40	50	60	70	80	90	100
F_ _ [?] ?	0	10	20	30	40	50	60	70	80	90	100
H_ _ [?] ?	0	10	20	30	40	50	60	70	80	90	100
G [?] ?	0	10	20	30	40	50	60	70	80	90	100
I [?] ?	0	10	20	30	40	50	60	70	80	90	100

PLEASE **WRITE IN** THE LAST LETTER OF EACH STRING BELOW. Do NOT make changes to your confidence judgments on the last page based on your recall experience.

B_ _ _ _ _ [?] __

D_ _ _ _ _ [?] __

F_ _ [?] __

H_ _ [?] __

G [?] __

I [?] __

***EYE TRACKING:* During the computer task, your eye movements were monitored. Please answer the following questions about this element of the computer task. You might have found wearing the eye tracking headgear to be uncomfortable or fatiguing.**

4) How uncomfortable did you find *wearing the headgear*? (please circle)
1……………….2……….………3……….………4……….………5
very uncomfortable not uncomfortable at all

5) How fatiguing did you find *wearing the headgear*? (please circle)
1……………….2……….………3……….………4……….………5
very fatiguing not fatiguing at all

6) How fatiguing did you find the *computer task in general*? (please circle)
1……………….2……….………3……….………4……….………5
very fatiguing not fatiguing at all

Please inform the Experimenter when you are finished.

Retrieval condition PTQ

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition: 2

POST-TESTING QUESTIONNAIRE

PART ONE: **In the first part of the computer task, you COMPUTED AND VERIFIED letter strings. Please answer the following questions about this part of the computer task.**

1) Rate how <u>difficult</u> you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART TWO: **In the second part of the computer task, you STUDIED AND WERE TESTED ON 6 letter strings. Please answer the following questions about the study-test portion of the computer task.**

2) Rate how <u>difficult</u> you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART THREE: **In this third part of the computer task, you verified the same 6 letter strings from part two, but could use either strategy to do so: *Compute or Memory*. Please answer the following questions about your performance of and use of strategies in this final part of the computer task.**

3) Rate how <u>difficult</u> you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

4) Were you <u>confident</u> to use your memory? **Please circle** a number below to indicate your level of confidence. **0 = not confident** **100 = very confident**

0 10 20 30 40 50 60 70 80 90 100

5) Rate how difficult you found using the *memory* strategy: **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

6) Estimate how often you used the *memory* strategy: **Please circle** a number below to indicate your percentage of memory strategy use. **0 = never used memory** **100 = always used memory**

0 10 20 30 40 50 60 70 80 90 100

7) How much do you think that *relying on memory* improves performance speed for this task? **Please circle** a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

8) Please rate how accurate *the memory strategy* is in comparison to *full computation*. **Please circle** a number below. **0 = much less accurate** **50 = equally accurate** **100 = much more accurate**

0 10 20 30 40 50 60 70 80 90 100

9) How much do you think that *relying on memory* for this task strengthens memory? **Please circle** a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

HOW CONFIDENT ARE YOU THAT YOU CAN RECALL THE LAST LETTER OF THE CORRECT LETTER STRINGS FROM PHASE 2 AND 3 WHEN PROMPTED WITH THE FIRST LETTER AND LIST LENGTH?

Please **circle** your confidence rating for each pair below.

0= won’t recall **100= definitely will recall**

B_ _ _ _ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

D_ _ _ _ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

F_ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

H_ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

G [?] ? 0 10 20 30 40 50 60 70 80 90 100

I [?] ? 0 10 20 30 40 50 60 70 80 90 100

PLEASE **WRITE IN** THE LAST LETTER OF EACH STRING BELOW. Do NOT make changes to your confidence judgments on the last page based on your recall experience.

B_ _ _ _ _ [?] __

D_ _ _ _ _ [?] __

F_ _ [?] __

H_ _ [?] __

G [?] __

I [?] __

Please inform the Experimenter when you are finished.

EYE TRACKING: **During the computer task, your eye movements were monitored. Please answer the following questions about this element of the computer task. You might have found wearing the eye tracking headgear to be uncomfortable or fatiguing.**

10) How uncomfortable did you find *wearing the headgear*? (please circle)

1……………….2……….………3……….………4……….………5

very uncomfortable not uncomfortable at all

11) How fatiguing did you find *wearing the headgear*? (please circle)

1……………….2……….………3……….………4……….………5

very fatiguing not fatiguing at all

12) How fatiguing did you find the *computer task in general*? (please circle)

1……………….2……….………3……….………4……….………5

very fatiguing not fatiguing at all

Please inform the Experimenter when you are finished.

SA Condition PTQ
POST-TESTING QUESTIONNAIRE

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition: 3

PART ONE: **In the first part of the computer task, you COMPUTED AND VERIFIED letter strings. Please answer the following questions about this part of the computer task.**

1) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART TWO: **In the second part of the computer task, you STUDIED AND WERE TESTED ON 6 letter strings. Please answer the following questions about the study-test portion of the computer task.**

2) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART THREE: **Before the third part of the experiment, you received instructions indicating that you could compute strings using only the triplet (e.g., F [4] K). In this third part of the computer task, you verified letter strings similar to part one, but could use either strategy to do so: *Compute or Triplet*. Please answer the following questions about your performance of and use of strategies in this final part of the computer task.**

3) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

4) Were you confident to use the *triplet strategy*? **Please circle** a number below to indicate your level of confidence. **0 = not confident** **100 = very confident**

0 10 20 30 40 50 60 70 80 90 100

5) Rate how difficult you found using the *triplet strategy*: **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

6) Estimate how often you used the *triplet strategy*: **Please circle** a number below to indicate your percentage of triplet strategy use. **0 = never used memory** **100 = always used memory**

0 10 20 30 40 50 60 70 80 90 100

7) How much do you think that *using the triplet strategy* improves performance speed for this task? **Please circle** a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

8) How much do you think that *using the triplet strategy* improves performance accuracy for this task? **Please circle** a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

9) Because deception is sometimes a necessary part of psychological experiments, participants might suspect deception even when none is being used. No deception was used in this experiment, but we are interested in whether participants might have suspected deception. We instructed you that alphabetical deviations would occur only in the triplet, but you might not have used the triplet strategy if you suspected that this instruction was deceptive. Did you doubt that the deviations occurred only in the triplet, despite the instructions? **Please circle one: YES NO**

If YES, What *percentage* of the time did you compute the entire string on this part of the task ***because*** you thought you were being deceived?
Please circle a number below. **0 = none of the trials** **100 = all of the trials**

0 10 20 30 40 50 60 70 80 90 100

HOW CONFIDENT ARE YOU THAT YOU CAN RECALL THE LAST LETTER OF THE CORRECT LETTER STRINGS FROM PHASE 2 WHEN PROMPTED WITH THE FIRST LETTER AND LIST LENGTH?

Please **circle** your confidence rating for each pair below.

0= won’t recall **100= definitely will recall**

B_ _ _ _ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

D_ _ _ _ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

F_ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

H_ _ [?] ? 0 10 20 30 40 50 60 70 80 90 100

G [?] ? 0 10 20 30 40 50 60 70 80 90 100

I [?] ? 0 10 20 30 40 50 60 70 80 90 100

PLEASE **WRITE IN** THE LAST LETTER OF EACH STRING BELOW. Do NOT make changes to your confidence judgments on the last page based on your recall experience.

B_ _ _ _ _ [?] __

D_ _ _ _ _ [?] __

F_ _ [?] __

H_ _ [?] __

G [?] __

I [?] __

EYE TRACKING: **During the computer task, your eye movements were monitored. Please answer the following questions about this element of the computer task. You might have found wearing the eye tracking headgear to be uncomfortable or fatiguing.**

10) How uncomfortable did you find *wearing the headgear*? (please circle)

1……………….2……….………3……….………4……….………5

very uncomfortable not uncomfortable at all

11) How fatiguing did you find *wearing the headgear*? (please circle)

1……………….2……….………3……….………4……….………5

very fatiguing not fatiguing at all

12) How fatiguing did you find the *computer task in general*? (please circle)

1……………….2……….………3……….………4……….………5

very fatiguing not fatiguing at all

Please inform the Experimenter when you are finished.

To be completed by Experimenter:
Participant #: _______
Date: ____/____/____
Condition: 4 cob:

Choice Condition PTQ

POST-TESTING QUESTIONNAIRE

PART ONE: **In the first part of the computer task, you COMPUTED AND VERIFIED letter strings. Please answer the following questions about this part of the computer task.**

1) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART TWO: **In the second part of the computer task, you STUDIED AND WERE TESTED ON 6 letter strings. Please answer the following questions about the study-test portion of the computer task.**

2) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

PART THREE: **Before the third part of the experiment, you received instructions indicating that you could compute strings using only the triplet (e.g., F [4] K). In this third part of the computer task, you verified the same 8 letter strings from part two, but could use several strategies to do so: *Compute, Memory, or Triplet*. Please answer the following questions about your performance of and use of strategies in this final part of the computer task.**

3) Rate how difficult you found this portion of the computer task. **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

USING THE MEMORY STRATEGY

4) Were you confident to use your memory? **Please circle** a number below to indicate your level of confidence. **0 = not confident** **100 = very confident**

0 10 20 30 40 50 60 70 80 90 100

5) Rate how difficult you found using the *memory* strategy: **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

6) Estimate how often you used the *memory* strategy: **Please circle** a number below to indicate your percentage of memory strategy use. **0 = never used memory** **100 = always used memory**

0 10 20 30 40 50 60 70 80 90 100

7) How much do you think that *relying on memory* improves performance speed for this task? **Please circle** a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

8) Please rate how accurate *the memory strategy* is in comparison to *full computation*. **Please circle** a number below. **0 = much less accurate** **50 = equally accurate** **100 = much more accurate**

0 10 20 30 40 50 60 70 80 90 100

9) How much do you think that *relying on memory* for this task strengthens memory?
Please circle a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

USING THE TRIPLET STRATEGY

10) Were you confident to use the *triplet strategy*? **Please circle** a number below to indicate your level of confidence. **0 = not confident** **100 = very confident**

0 10 20 30 40 50 60 70 80 90 100

11) Rate how difficult you found using the *triplet strategy*: **Please circle** a number below to indicate the level of difficulty. **0 = not difficult** **100 = very difficult**

0 10 20 30 40 50 60 70 80 90 100

12) Estimate how often you used the *triplet strategy*: **Please circle** a number below to indicate your percentage of triplet strategy use. **0 = never used memory** **100 = always used memory**

0 10 20 30 40 50 60 70 80 90 100

13) How much do you think that *using the triplet strategy* improves performance speed for this task? **Please circle** a number below. **0 = not at all** **100 = very much**

0 10 20 30 40 50 60 70 80 90 100

14) Please rate how accurate *the triplet strategy* is in comparison to *full computation*. **Please circle** a number below. **0 = much less accurate** **50 = equally accurate** **100 = much more accurate**

0 10 20 30 40 50 60 70 80 90 100

15) Because deception is sometimes a necessary part of psychological experiments, participants might suspect deception even when none is being used. No deception was used in this experiment, but we are interested in whether participants might have suspected deception. We instructed you that alphabetical deviations would occur only in the triplet, but you might not have used the triplet strategy if you suspected that this instruction was deceptive. Did you doubt that the deviations occurred only in the triplet, despite the instructions? **Please circle one: YES NO**

If YES, What *percentage* of the time did you compute the entire string on this part of the task ***because*** you thought you were being deceived?
Please circle a number below. **0 = none of the trials** **100 = all of the trials**

0 10 20 30 40 50 60 70 80 90 100

HOW CONFIDENT ARE YOU THAT YOU CAN RECALL THE LAST LETTER OF THE CORRECT LETTER STRINGS FROM PHASES 2 AND 3 WHEN PROMPTED WITH THE FIRST LETTER AND LIST LENGTH?

Please **circle** your confidence rating for each pair below.

0= won't recall **100= definitely will recall**

B_ _ _ _ _ [?] ? 0 10 20 30 40 50 60 70 80
90 100

D_ _ _ _ _ [?] ? 0 10 20 30 40 50 60 70 80
90 100

F_ _ [?] ? 0 10 20 30 40 50 60 70 80
90 100

H_ _ [?] ? 0 10 20 30 40 50 60 70 80
90 100

G [?] ? 0 10 20 30 40 50 60 70 80
90 100

I [?] ? 0 10 20 30 40 50 60 70 80
90 100

PLEASE **WRITE IN** THE LAST LETTER OF EACH STRING BELOW. Do NOT make changes to your confidence judgments on the last page based on your recall experience.

B_ _ _ _ _ [?] __

D_ _ _ _ _ [?] __

F_ _ [?] __

H_ _ [?] __

G [?] __

I [?] __

EYE TRACKING: **During the computer task, your eye movements were monitored. Please answer the following questions about this element of the computer task. You might have found wearing the eye tracking headgear to be uncomfortable or fatiguing.**

16) How uncomfortable did you find *wearing the headgear*? (please circle)
1……………….2……….………3……….………4……….………5
very uncomfortable not
uncomfortable at all

17) How fatiguing did you find *wearing the headgear*? (please circle)
1……………….2……….………3……….………4……….………5
very fatiguing not fatiguing
at all

18) How fatiguing did you find the *computer task in general*? (please circle)
1……………….2……….………3……….………4……….………5
very fatiguing not fatiguing
at all

Please inform the Experimenter when you are finished.

APPENDIX O

GAZE COUNTS AND DURATIONS

Phase 1 triplet gaze counts

	+0		+1		+2		+3		+4	
	M	SD	M	SD	M	SD	M	SD	M	SD
Young	5.47	1.82	5.80	1.56	5.11	1.55	4.91	1.39	4.64	1.39
Old	6.35	2.52	6.60	2.11	5.83	1.94	6.04	2.46	5.37	2.13

Note. +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

Phase 1 gaze durations

	Non-Triplet		Triplet	
	M	*SD*	*M*	*SD*
Young	379	213.7	486	190.7
Old	307	90.5	442	185.0

Note. Means of median gaze durations in milliseconds.

Phase 3 Control condition gaze counts to the triplet

	+0		+2		+4	
	M	SD	M	SD	M	SD
Young	3.75	0.84	3.84	0.61	3.76	0.64
Old	6.06	2.16	6.07	2.14	5.63	2.02

Note. +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

Phase 3 Retrieval condition gaze counts to the triplet

	Comp						Ret					
	+0		+2		+4		+0		+2		+4	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Young	5.47	2.41	4.79	1.92	4.28	2.39	2.71	0.42	2.08	1.09	1.85	0.73
Old	6.93	4.81	9.91	6.09	5.03	2.73	2.80	1.39	2.16	0.75	2.10	0.73

Note. Comp = computation strategy; Ret = retrieval strategy; +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

Phase 3 SA condition gaze counts to the triplet

	Comp						SA					
	+0		+2		+4		+0		+2		+4	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Young	5.14	2.33	5.00	1.09	5.67	2.13	4.94	0.95	4.19	1.17	4.26	1.58
Old	8.56	5.52	6.89	2.89	7.36	2.99	5.18	2.75	4.47	2.37	6.00	2.61

Note. Comp = computation strategy; SA = selective attention strategy; +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

Phase 3 Choice condition gaze counts to the triplet

	Comp						Ret						SA					
	+0		+2		+4		+0		+2		+4		+0		+2		+4	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Young	4.7	2.09	5.5	0.50	5.0	2.71	2.1	0.45	2.2	1.84	2.0	2.07	4.0	0.00	6.4	3.19	4.6	2.63
Old	6.5	1.21	7.0	1.36	6.7	1.20	2.6	0.45	2.6	3.33	1.6	0.39	8.1	5.13	6.5	0.52	7.4	2.24

Note. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy; +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

Phase 3 gaze duration for non-triplet gazes

	Control				Retrieval				Selective Attention				Choice			
	Young		Old		Young		Old		Young		Old		Young		Old	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Comp	321	78.7	294	53	347	180	284	67.6	308	58.1	275	115	250	33.6	283	52.1
Ret					225	49.1	228	55					213	64.5	213	36.9
SA									258	75	264	140	253	25.8	253	73.4

Note. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy. Means of median gaze durations in milliseconds.

Phase 3 gaze duration for non-triplet gazes

	Control				Retrieval				Selective Attention				Choice			
	Young		Old		Young		Old		Young		Old		Young		Old	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Comp	321	78.7	294	53	347	180	284	67.6	308	58.1	275	115	250	33.6	283	52.1
Ret					225	49.1	228	55					213	64.5	213	36.9
SA									258	75	264	140	253	25.8	253	73.4

Note. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy. Means of median gaze durations in milliseconds.

APPENDIX P

CHOICE CONDITION RT'S AND NON-TRIPLET GAZE COUNTS

Choice condition RTs

	Comp						Ret						SA					
	0		2		4		0		2		4		0		2		4	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Young	7680	6473	6145	889	5815	1334	1265	623	1545	713	1601	802	4449	2626	4575	1789	4769	663
Old	7013	1053	6869	1161	7516	886	1869	754	2051	1116	2121	549	5281	2088	3798	1200	5445	861

Note. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy; +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

Phase 3 Choice condition gaze counts to the non-triplet

	Comp				Ret				SA			
	+2		+4		+2		+4		+2		+4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Young	2.7	0.58	5.9	2.46	1.6	0.48	1.8	0.38	1.7	0.79	2.0	0.70
Old	4.6	1.00	7.0	1.06	2.0	0.51	2.5	0.74	1.0	0.87	2.1	1.77

Note. Comp = computation strategy; Ret = retrieval strategy; SA = selective attention strategy; +0 = triplet only strings; +2 = triplet plus two additional letters; +4 = triplet plus four additional letters.

APPENDIX Q

CHOICE CONDITION CORRELATIONS

Correlations Between Strategy Use and Metacognitive Ratings for the Choice Condition

	Overall	Young	Old	Retrieval	SAS	Young Ret.	Old Ret.	Young SAS	Old SAS
Confidence	**.41**	**.49**	**.45**	**.62**	**.38**	**.57**	**.66**	.33	.44
Difficulty	-.21	**-.48**	-.08	**-.46**	-.17	**-.81**	-.24	-.13	-.22
Accuracy	.27	.32	.26	**.53**	**.40**	**.44**	**.61**	.13	**.59**
Speed	-.27	-.15	-.42	.22	.29	.37	.09	.19	.40

Note. Bolded correlations are significant at the $p < .05$ level.