THE EFFECTS OF PERFORMANCE GOALS ON THE AUTOMATICITY OF COGNITIVE SKILLS

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INTRODUCTION

Practice effects on cognitive skills are among the most robust findings in cognitive psychology. Indeed, a voluminous amount of research has shown speed and accuracy gains during the practice of various cognitive tasks with a diversity of learners (e.g., Anderson, Fincham, & Douglass, 1999; Logan, 1988; McAndrews & Moscovitch, 1990; Rawson, 2004; Rawson & Middleton, 2009; Rawson & Touron, 2009; Schneider & Shiffrin, 1977; Touron & Hertzog, 2004; Touron, Swaim, & Hertzog, 2007; Wilkins & Rawson, in press). According to memory based processing (MBP) theories of automaticity (e.g., Logan, 1988; Palmeri, 1997; Rickard, 1997), speed gains during practice are due to a shift from an item-general algorithmic process to an item-specific memory-based process. For example, without a calculator, when one first attempts to solve the problem 24 X 7, one would have to compute the answer (168) using item-general algorithmic rules of multiplication, rules that can be applied to any multiplication problem. After multiple exposures to the same problem, eventually one will be able to answer by retrieving the answer directly from memory, which is item-specific because retrieving the answer to this problem would not help in answering another multiplication problem (e.g., 32 X 8).

The transfer to memory-based processing has been extensively studied in the automaticity literature, with questions ranging from whether transfer to memory retrieval is a gradual or abrupt process (Rickard, 1997) to what information is encoded for later retrieval during skill acquisition (Lassaline & Logan, 1993; Logan & Etherton, 1994) to the duration of memory retrieval after practice (Grant & Logan, 1993; Wilkins & Rawson, in press). In contrast, the extent to which participants can control transfer to memory retrieval has been less well examined (see Bourne, Raymond, & Healy, 2010; Reder & Ritter, 1992; Touron & Hertzog, 2004). Thus, the primary goal of the current research was to further explore the extent to which individuals can control involvement of retrieval during skill acquisition. Of secondary interest, to the extent individuals can control transfer to retrieval during skill acquisition, I also explored the extent to which differential involvement of retrieval during practice has consequences for subsequent processing after practice.

Below, MBP theories of automaticity will be explained in more detail, particularly Logan's (1988) instance theory. Next, I describe how MBP theories of automaticity currently account for individuals' control of retrieval use, followed by a brief review of the available evidence for control of retrieval. Finally, I describe how MBP theories of automaticity account for the later consequences of differential strategy use during practice, followed by a summary of available evidence of the consequences of differential retrieval during practice.

Memory-Based Theories of Automaticity.

To account for the transfer from item-general algorithmic processing to item-specific memory-based processing, Logan's (1988) instance theory has three main assumptions. First, instance theory assumes that the item-general algorithmic process races in parallel with the item-specific memory-based process when a stimulus is presented. The process that wins the race is the process that generates the response. On the first encounter with a specific stimulus, the item-general algorithmic process wins the race, as there are no available traces in memory for retrieval to enter the race. However, after multiple exposures to a specific stimulus, traces are available in memory to race against the algorithm. The speed any one trace can be retrieved from memory varies from one moment to the next. Thus, the more traces stored in memory the greater the likelihood that a trace will be retrieved quickly and relative to the speed of the algorithm the greater the likelihood that retrieval will win the race.

Second, instance theory assumes that every time an individual is exposed to a specific stimulus, a unique trace (instance) for the event is encoded into memory. That is, encoding instances into memory is obligatory, an unavoidable consequence of attention and simply attending to a stimulus is sufficient to encode it into memory (Logan, 1988). Thus, if a specific stimulus has been encountered and responded to by an individual 20 times, on the 21st presentation there are 20 instances that race against the algorithm. Although a unique memory trace for a specific stimulus is encoded every time the stimulus is encountered, Logan (1988) notes that encoding quality may depend on the quality and quantity of attention.

Third, instance theory assumes that every time an individual is exposed to a specific stimulus, retrieval of instances from memory occurs. That is, retrieval from memory is obligatory. Attending to a specific stimulus is sufficient to initiate retrieval of any previous instances stored in memory for the stimulus (Logan, 1988). Although instance theory assumes that initiation of retrieval is obligatory, Logan (1988) notes that successful retrieval does not always occur. Rather, attending to a stimulus is sufficient to start the retrieval process.

Although another MBP theory of automaticity has been developed after Logan's (1988) instance theory (see Palmeri, 1997), both share the previously described assumptions of instance theory and thus both offer the same explanations regarding our questions of interest. Concerning the extent to which participants can control the involvement of retrieval during skill acquisition, MBP theories of automaticity do not include a top-down control mechanism for the inhibition of memory retrieval. The only mechanism of MBP theories relevant to process selection is obligatory retrieval. Given the assumption that attending to a stimulus is sufficient to initiate the memory retrieval process, MBP theories in their current form suggest that individuals have no control over the involvement memory retrieval. At most, Logan (1988) notes, after retrieval, participants can then decide to respond on the basis of the retrieved information or continue to use the algorithm.

Can Individuals Control Involvement of Memory Retrieval

Although instance based MBP theories of automaticity suggest that individuals have no control over the involvement of memory retrieval, results from a few existing studies suggest that participants may at least have partial control over process selection (Bourne et al., 2010; Reder & Ritter, 1992; Touron & Hertzog, 2004). For example, Bourne et al. (2010) had participants practice repeatedly classifying letter strings based on whether a target letter within the string was a vowel or a consonant. In addition, on each trial, participants reported whether they used an algorithmic process or a memory retrieval process to answer. In order to examine if participants could control process selection during skill acquisition, Bourne et al. manipulated algorithm pretraining. They found that the proportion of trials in which participants reported retrieving answers from memory (i.e., reported retrieval use) was greater when participants were pretrained with the relevant algorithm than when participants were not pretrained. Bourne et al. also manipulated cue-to-rule salience by placing the target letter at the start of the letter string for half of the participants and at the end of the letter string for half of the participants. Reported retrieval use was greater when the target letter was at the end of the letter string than when the target letter was at the start of the letter string. Bourne et al. also manipulated the presence of novel items during training, with half of participants periodically presented novel items during training. Reported retrieval use was greater for participants presented novel items than for participants not presented novel items. Bourne et al. (2010) offer an interesting explanation for their results that contrasts sharply with current instance based MBP theories of automaticity. According to Bourne et al., participants evaluate the costs and benefits of both the algorithmic process and the retrieval process. During the task, participants compare the costs and benefits of each process. The process that has the most benefits over costs is the process selected by the individual to answer a given trial. Thus, according to Bourne et al., participants not pretrained with the relevant algorithm used memory retrieval less often during training because the effort required discovering the relevant algorithm during training increased their subjective value for the algorithm relative to retrieval. Likewise placing the target cue at the end of the letter string presumably caused participants to use memory retrieval more often because the time taken to scan to the end of the stimulus increased the costs for the algorithmic process. Presenting novel items presumably increased the benefits of the algorithm relative to memory retrieval because participants were made aware of the fact that one can solve a wider array of stimuli using the algorithmic process than using the retrieval process, given that novel items by definition must be responded to by use of the algorithm.

Although Bourne et al. (2010) attributed their results to controlled use of retrieval based on cost-benefit comparisons, MBP theories of automaticity may still account for their results without the assumption of control. To revisit, MBP theories of automaticity state that the speed of retrieval depends on the number of traces stored in memory for a given stimulus and that the likelihood of retrieval depends on the relative speed at which the algorithm can be completed. In Bourne et al.'s task, speed of retrieval and speed of algorithm completion were nearly identical, as evidenced by response times not being significantly different between trials in which participants reported retrieval use and trials in which participants reported algorithm use. Given that algorithm speed is likely slower for targets at the end of the letter string than at the start of the letter string, it is not surprising that less algorithm use was reported for last-letter participants than for first-letter participants. Concerning pretraining, participants not pretrained had to discover the relevant algorithm during the beginning of training. Thus, for these beginning trials, participants at best were not able to encode traces into memory and at worst encoded incorrect traces into memory. If there are no instances stored in memory to race against the algorithm, the algorithm wins the race by default, explaining why participants with no pretraining used retrieval less than pretrained participants.

The only effect that presents difficulty for MBP theories of automaticity is the presence of novel items. Again, according to MBP theories of automaticity, speed of retrieval only depends on the number of traces stored in memory and the likelihood of retrieval being used is relative to the speed of the algorithm. Thus, given that periodic presentations of novel items throughout training likely had little affect on the speed of the algorithm, MBP theories of automaticity would predict that retrieval use would not be affected by the presence of novel items. If anything, MBP theories of automaticity would predict that retrieval speed would increase with practice because the number of memory-traces for a given item increases each time the item is presented.

Stronger evidence that individuals may have partial control over process selection during skill acquisition comes from Touron and Hertzog (2004). In their Experiment 3, older adults and younger adults were trained on a noun-pair lookup task. For a standard training trial, participants were presented with a noun pair and a lookup table containing a list of noun pairs. Participants were required to indicate whether the target noun pair was in the table. The table consisted of the same noun pairs throughout the experiment, although their order was randomized anew for each trial. After half of the standard training trials, participants reported whether they use retrieval or the algorithm to respond. Importantly, in order to examine if participants could control process selection during skill acquisition, participants were also presented with memory-probe trials during training. During memory-probe trials, the noun-pairs presented were the same as presented for standard training trials. Although participants were still tasked with deciding if noun pairs were in the lookup table during memory-probe trials, the lookup table was not presented to participants during memory-probe trials, only the noun-pair was presented. Thus, for a memory-probe trial, participants had to use retrieval to decide if the lookup table presented during standard training trials contained the presented noun-pair. Touron and Hertzog found that accuracy on memory-probe trials did not significantly differ between older and younger adults, suggesting that the ability to use retrieval was not significantly different between older and younger adults. However, although the ability to use retrieval did not significantly differ between older and younger adults, reported retrieval use on training trials was significantly less for older adults than for younger adults, suggesting that older adults had an aversion to using the retrieval process and were able to partially control their use of retrieval.

Further evidence from Touron and Hertzog (2004) suggests that individuals partially control the involvement of retrieval during skill acquisition by making cost-benefit evaluations for the retrieval process at the task-level. In their Experiment 3, following training, participants were measured for their belief in the utility of the retrieval process for the noun-pair lookup task. Touron and Hertzog found that participants' belief in the utility of the retrieval process for the noun-pair lookup task was correlated with reported retrieval use. Compared to younger adults, older adults were less confident in their ability to use retrieval in the noun-pair lookup task and rated retrieval as more effortful.

Complementing Touron and Hertzog's (2004) results suggesting that participants can partially control the involvement of retrieval by making task-level judgments concerning the value of the retrieval process, Reder and Ritter (1992) found results that suggest individuals can make item-level cost-benefit comparisons for process use. Participants were trained on relatively novel arithmetic problems, which were repeated a varying number of times during training. Key here, participants were required to make a speeded judgment on each trial concerning whether they could retrieve the answer from memory or had to compute the answer. Participants were given 850 milliseconds to decide, which according to Reder and Ritter was faster than the time needed to actually retrieve answers from memory. If participants chose to retrieve, they were given approximately 1 second to respond. If participants chose to use the algorithm, they were given approximately 18 seconds to respond.

Important here, Reder and Ritter (1992) found that when participants decided to retrieve the answer they accurately responded in less than 1 second. Furthermore, response times decreased and the decision to use memory retrieval increased as practice with each item increased, consistent with the possibility that participants can control the involvement of retrieval during skill acquisition by evaluating the costs and benefits of each process for each item.

In sum, although MBP theories of automaticity do not explicitly include mechanisms for individual control of retrieval during skill acquisition, a small number of studies suggest that individuals have at least partial control over the involvement of retrieval during skill acquisition (Bourne et al., 2010; Reder and Ritter, 1992; Touron &

Hertzog, 2004). Clearly, more research is needed to establish whether individuals can control the involvement of retrieval during skill acquisition. Furthermore, research also needs to identify factors that influence control over the involvement of retrieval during skill acquisition. Accordingly, the primary goal of the current research was to further establish the extent to which learners can control the involvement of retrieval during skill acquisition by examining a new factor, performance goal.

One way to influence learners' goals for performing a task is to manipulate task instructions. Instructions requiring learners to perform a task as accurately as possible should influence them to use the algorithm process more than the retrieval process because algorithms are believed to more reliably produce correct response than retrieval (cf. Touron & Hertzog, 2004). In contrast, instructions requiring learners to perform the task as fast as possible should influence them to use the retrieval process more than the algorithm because retrieval is usually faster than the algorithm. Thus, manipulating learners' task instructions to influence their performance goals to either perform the task as accurately as possible or as quickly as possible should affect the proportion of algorithmic and retrieval process use during skill acquisition. Accordingly, all three experiments presented here instructed participants that their primary goal was to answer either as accurately as possible (referred to as the accuracy group hereafter) or as quickly as possible during practice (referred to as the speed group hereafter).

Different proportions of process use can be measured by response times across blocks, on the condition that different processes have different associated response times. Unlike Bourne et al.'s (2010) task, in which response times across practice were not significantly different between algorithm and retrieval processes, response times for tasks traditionally used in automaticity research are typically greater for the algorithmic process than for the retrieval process (e.g., Rickard, 1997; Rickard, Lau, & Pashler, 2008; Touron & Hertzog, 2004, Wilkins & Rawson, in press). Accordingly, all three experiments used a traditional alphabet arithmetic (AA) verification task (Compton & Logan, 1991; Logan, 1988; Logan & Klapp, 1991), in which participants verify if AA problems (e.g., A + 2 = C) are true or false.

In addition to manipulating task instructions to influence performance goal, all three experiments also included sets of novel AA items mixed with a set of repeated AA items in every 6th block of practice. Together, the between subject manipulation of task instructions and the within subject manipulation of item type offer three predictions relevant to the examination of the extent to which participants' goals influence their control over the involvement of retrieval during skill acquisition.

Prediction 1 involves comparing response time differences between novel and repeated items for each group (accuracy versus speed) to examine the extent to which participants can control the involvement of retrieval during skill acquisition. To revisit, novel items by definition must be solved by use of the algorithmic process. Given that for the AA verification task, response times are slower for the algorithmic process than for the retrieval process, there are two possible outcomes for my first prediction of each experiment, depending on the extent in which participants can control the involvement of retrieval. The strong version of Prediction 1 assumes that participants exert complete control over the involvement of the retrieval process. If the strong version is correct, response times should not significantly differ between novel items and repeated items for the accuracy group, but should be significantly slower for novel items than for repeated items for the speed group. The weak version of Prediction 1 assumes that participants only exert partial control the involvement of retrieval during skill acquisition. If the weak version is correct, response times will be significantly slower for novel items than for repeated items for both groups, but the difference between novel and repeated items would be less for the accuracy group than for the speed group. Regardless of which version of Prediction 1 is correct, both versions predict an interaction for response times between item type and group because the algorithm is used to respond to repeated items more for the accuracy group than for the speed group.

Prediction 2 involves comparing response times for repeated items between groups across each block of practice to examine the extent to which participants control the involvement of retrieval during skill acquisition. If participants can control the involvement of retrieval use during skill acquisition, response times for repeated items across blocks of practice should be slower for the accuracy group than for the speed group because the accuracy group will be using the slower algorithmic process on a proportion of the repeated items in each block. However, mean response times for repeated items between groups will not diverge until later in practice. At the beginning of practice, both groups will be using the algorithmic process to respond because traces have yet to be stored in memory.

Prediction 3 involves comparing response times for repeated items between blocks with novel items present to preceding blocks without novel items to examine the extent to which participants can control the involvement of retrieval during skill acquisition. To revisit, Bourne et al. (2010) suggested that presenting novel items during practice increased the benefits of the algorithm relative to memory retrieval because participants were made aware of the fact that they can solve a wider array of stimuli using the algorithmic process than using the retrieval process. If Bourne et al.'s interpretation is correct then response times for repeated items should be slower for blocks with novel items present than for preceding blocks without novel items because use of the retrieval process will be less in blocks with novel items than in blocks without novel items.

Consequences of Individual's Control for Subsequent Performance

Given that MBP theories of automaticity do not include a top-down mechanism for control of retrieval use, they also are silent as to the consequences of such control for later performance. According to the obligatory encoding assumption of MBP theories of automaticity, encoding into memory is an unavoidable outcome of attending to a stimulus. Thus, MBP theories of automaticity would predict no consequence for controlling process use during practice on later performance. Regardless of learners' performance goals, if practice involves the same number of items repeated for the same number of times, the same numbers of traces are stored in memory for each practiced item. However, there are accounts that would predict consequences of differential process use during practice on later performance. Logan (1988) notes one account, the quality of encoding may depend on the quality and quantity of attention given to a stimulus. As a second account, transfer appropriate processing (TAP) assumes that performance will be greatest when processing during practice matches processing during test. If either Logan or TAP is correct, differential processing during practice would have consequences for later performance. According to Bourne et al. (2010), more time is spent encoding information when the algorithmic strategy is used than when the retrieval strategy is used. Thus, if time spent processing influences the quantity and quality of attention, response times for practiced items during test would be faster for the accuracy performance goal group than for the speed performance goal group. If TAP is correct, response times for practiced items during test would be faster for the speed performance goal group than for the accuracy performance goal group.

In the only previous study to examine the consequence of process use during practice, Logan and Klapp (1991, Experiment 4) used the AA verification task to directly compare learning by rote memory to learning by performing the task. The experiment involved a practice session and a test session in which each problem was repeatedly presented. During practice, all participants saw AA problems followed by their truth value (TRUE or FALSE). The learn-by-memory group first read the problem and then pressed a key to see the correct answer (TRUE or FALSE). Participants of this group were instructed to associate the answer with the problem. The learn-by-doing group read the problem and then pressed one of two keys indicating whether the question was true or false. The test session immediately followed the practice session. During the test session, all participants were instructed to learn by doing. If how instances are encoded into memory matters, the two groups should have differed in performance during the test session. However, Logan and Klapp found no significant differences between learn-by-memory and learn-by-doing groups during test, suggesting that differential process use during practice does not have consequences for later performance.

Although Logan and Klapp's (1991) results suggest there are no consequences of differential encoding during practice for later performance of a cognitive skill, this is the only experiment examining differential encoding during practice. Thus the secondary goal of the current research was to further examine the extent to which there are consequences of differential process use during practice on later performance.

To further examine the extent to which there are consequences on later performance due to differential process use during practice, the current experiments each included a test session seven days after the practice session. During the test session previously seen items were again repeated, with all participants instructed that their primary goal was to answer as fast as possible. If differential process use during practice does have consequences on later performance, response times for repeated items in the first block of test should be significantly different between the accuracy and speed groups. I only test the first block of test because it is the only block not contaminated by practice gains made during the test session.

In sum, the primary goal of the current research was to further establish the extent to which learners can control the involvement of retrieval during skill acquisition by examining a new factor, performance goal. Of secondary interest, the current research also sought to further examine the extent to which there are consequences of differential process use during practice on later performance.

METHOD EXPERIMENT 1

Participants and Design

Seventy-one undergraduates from Kent State University completed the experiment in exchange for research credit in an introductory psychology class. Participants were randomly assigned to one of two practice groups, defined by the instructions to participants regarding their primary goal in practice (accuracy or speed).

Materials

Experimental stimuli consisted of 120 AA problems. Half of the AA problems were false (e. g. S + 2 = V) and half were true (e. g. B + 3 = E). A third of the AA problems were of addend size 2 (e. g. A + 2 = C), a third were of addend size 3 (e. g. A + 3 = D), and a third were of addend size 4 (A + 4 = E).

Procedure

The AA problems were divided into ten sets. Each set consisted of six true and six false problems, with equal numbers of true and false problems of each addend size. Assignment of sets to conditions was counterbalanced across participants. One set was assigned to the *repeated condition*, with each item presented for 36 blocks during practice and 12 blocks during test. The remaining nine sets were assigned to the *novel condition*, with six sets presented during practice and three sets presented during test. Each of the six novel sets presented during practice was presented for one block, with individual sets randomly assigned to blocks 6, 12, 18, 24, 30, and 36. Each of the three novel sets presented during test was presented for one block, with individual sets randomly assigned to blocks 1, 6, and 12.

The primary manipulation involved the instructions given to participants at the beginning of the practice session. In both groups, participants first read instructions explaining the AA verification task and were given examples of true and false problems. For the accuracy group, participants then read instructions for their task goal: "Although you should try to answer all problems quickly, **YOUR PRIMARY GOAL IS TO BE AS ACCURATE AS POSSIBLE**". For the speed group, participants then read instructions for their task goal: "Although you should try to answer all problems accurately, **YOUR PRIMARY GOAL IS TO BE AS FAST AS POSSIBLE**". After reading instructions, participants completed six true and six false example problems to become familiar with the task. The 12 examples were only used as warm-up problems and were not presented to participants during practice. Upon completion of the warm-up trials, participants were given feedback concerning their average response speed and accuracy and were also reminded of their primary and secondary goals. The experimenter then checked participants' performance to ensure they had completed the warm-up problems appropriately. At this time, the experimenter also verbally reminded them of their primary and secondary goals. For the accuracy group, the experimenter instructed the participant that although they should try to answer as quickly as possible, their primary goal was to be as accurate as possible. For the speed group, the experimenter instructed the participant that although they should answer as accurately as possible, their primary goal was to answer as quickly as possible. The experimenter then answered any other questions participants had about the procedure before starting the experimental trials.

In each of the 36 blocks, the order of repeated items was randomized anew, with 12 practice novel items randomly dispersed within every 6th block. On each trial, an orientation stimulus (***) was presented for 500 ms, followed by an AA problem and two response buttons ("TRUE" and "FALSE") appearing below the AA problem. After participants clicked on a response button, the stimulus and the response buttons disappeared. If the response was incorrect, a red "ERROR" message was presented for 1000 ms, followed by a button labeled "next". If the participant's response was correct, the "next" button was immediately presented. The participant clicked on the "next" button to present the orientation stimulus for the next trial, followed by the next AA problem, and so on. Response time was recorded as the time between stimulus onset and clicking one of the two response buttons. Feedback concerning average speed and accuracy was presented after approximately every 48 trials, at which point the task goals were again emphasized. Participants were also given the opportunity to take a small break during the presentation of feedback. Upon completion of the practice session, participants were dismissed and reminded to return in seven days.

At the beginning of the test session, all participants read instructions and performed warm-up problems. Importantly, for the test session, all participants were instructed to answer as quickly as possible. After the warm-up problems, participants were given feedback concerning their average response speed and accuracy and were also reminded of their primary and secondary goals. The experimenter then checked participants' performance to ensure they had completed the warm-up problems appropriately. At this time, the experimenter also verbally reminded them of their primary and secondary goals. For both groups, the experimenter instructed participants that although they should answer as accurately as possible, their primary goal was to answer as quickly as possible. The experimenter then answered any other questions participants had and then began the experimental trials. In each of the 12 blocks, the order of repeated items was randomized anew, with 12 practice novel items randomly dispersed within blocks 1, 6, and 12. Trials were presented in the same manner as the practice session.

Results

Data for six participants were dropped from analyses because of performance below 75% accuracy in either the practice or the test session. Accuracy was near ceiling throughout the experiment, with no significant differences in accuracy during practice between the accuracy group (M = 95.0%, SE = 1.0) and the speed group (M = 93.8%, SE = 0.8), $t(63) = 0.92$, $p = .36$. Differences in accuracy during the test session approached significance, with accuracy greater for the accuracy group (M = 96.3%, SE = 0.5) than for the speed group (M = 94.5%, SE = 0.9), $t(63) = 1.80$, $p = .08$.[1] Analyses of response times were conducted on correct response trials only (excluding response times less than

[1] Although the trend for overall accuracy to be greater for the accuracy group than for the speed group was not significant in Experiment1, the trend was also apparent in Experiments 2 and 3. Finding this trend across experiments is not surprising and is to be expected given the instructional manipulations asked participants to be as fast as possible or as accurate as possible. The trend does not offer interpretive difficulties, as all analyses were conducted on correct trials only.

50 ms and greater than 9000 ms, < 1% of trials). To minimize the effects of outliers, raw response times were first log transformed, averaged over trials for each participant, and then individual averages were anti-log transformed (Wilkins & Rawson, in press; see also Rickard, 1997, 2007).

For each participant, response times for the 12 repeated items were averaged for each block of practice and for each block of test. Similarly, for blocks containing novel items, response times for the 12 novel items were averaged. Mean response times for repeated and novel items in each group for each block are presented in Figure 1.

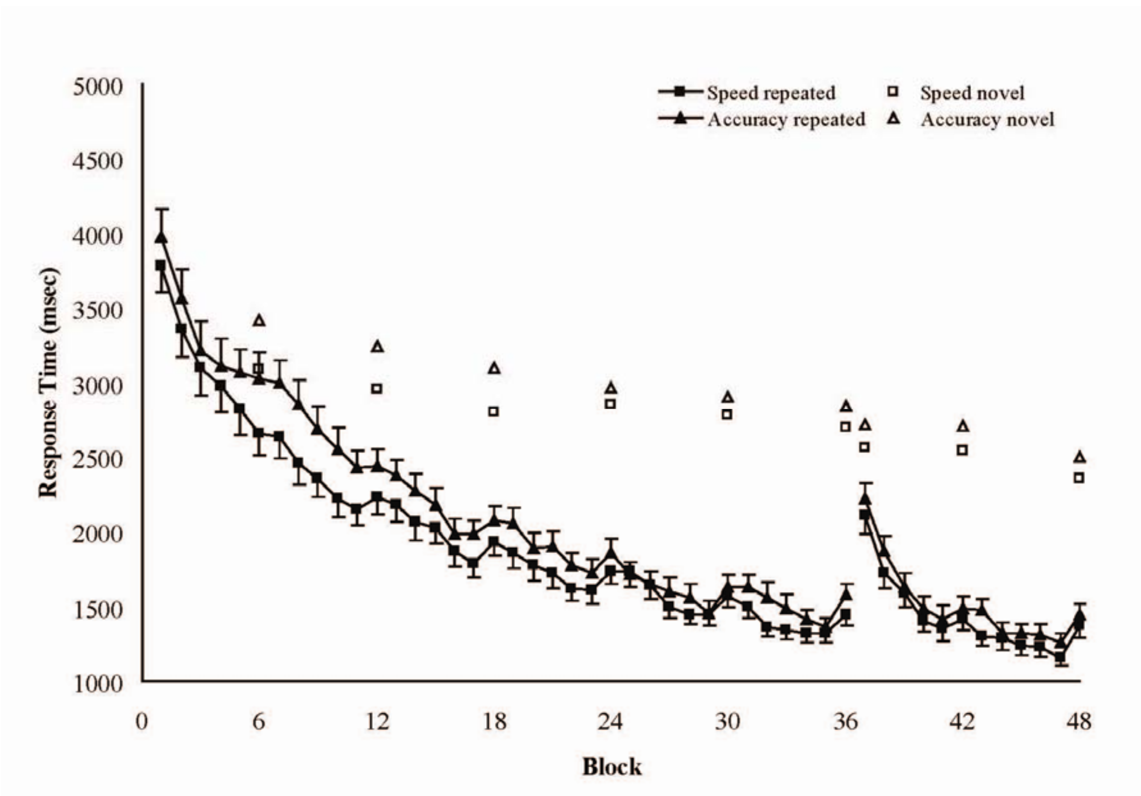

Figure 1. Experiment 1 mean response times as a function of performance goal group, blocks of trials, and experimental session. Response times are further separated into novel-item and repeated items blocks, where applicable in practice and test sessions.

Below, I first consider performance during the practice session, as it relates to my primary question of interest: To what extent do participants' performance goals influence their control over the involvement of memory retrieval during skill acquisition? I then turn to test session data, as it relates to my secondary question: To the extent that participants' performance goals influence their control over the involvement of memory retrieval during skill acquisition, what are the consequences for later performance?

Practice session. To revisit Prediction 1, if participants completely control the involvement of retrieval strategy during practice, response times should not be significantly different between novel and repeated items in the accuracy group. As is clear from inspection of Figure 1, this was not the case. Response times were slower for novel items than for repeated items in both groups. A 2 (item: repeated, novel) X 2 (group: accuracy, speed) mixed factor ANOVA resulted in a significant main effect of item type, $F(1,63) = 230.25$, MSE = 129490, $p < .001$. Response times were significantly faster for repeated items (M = 2015 ms, SE = 59 ms) than for novel items (M = 2973 ms, SE = 85ms). However, neither the main effect of group nor the interaction with group was significant, $F(1,63) = 2.27$, $p = .14$ and $F < 1$ respectively. Taken together, the results indicate participants in the accuracy group did not completely avoid use of retrieval.

However, concerning Prediction 2, if retrieval from memory was completely obligatory, response times for practiced items would not differ between the accuracy group and the speed group. As is clear in Figure 1, response times for repeated items are consistently slower for the accuracy group than for the speed group. A 2(group: accuracy, speed) X 36(block) mixed factor ANOVA resulted in a significant main effect of block, $F(35,2205) = 139.83$ MSE = 192064, $p < .001$. Neither the main effect of group nor the group X block interaction was significant, $F(1,63) = 1.76$, MSE = 9536888, $p = .19$ and $F < 1$ respectively. Follow up 1-tail *t*-tests comparing response times for repeated items between the accuracy group and the speed group for each block revealed that response times were significantly slower for the accuracy group than for the speed group early in practice (blocks 6 thru 11, all *t*s > 1.65, all *p*s < .05), which is consistent with the possibility that participants of the accuracy group were at least partially successful in controlling their involvement of retrieval.

In addition, concerning Prediction 3, if the presence of novel items increased use of the algorithmic process for repeated items, response times for repeated items will be slower for blocks with novel items than for preceding blocks without novel items. An inspection of Figure 1 indicates that this was the case. Tests comparing response times for repeated items in blocks containing novel items to the preceding blocks are reported in Table 1.

Table 1: Experiment 1 response times for repeated items: Blocks with novel items present versus preceding blocks.

Group	Comparison Blocks	Preceding Block M (SE)	Novel Block M (SE)	*t*-test Value (Sig.)
Accuracy				
	5 to 6	3062 (164)	3026 (174)	0.50 (.623)
	11 to 12	2423 (114)	2435 (118)	0.17 (.865)
	17 to 18	1981 (97)	2074 (90)	1.87 (.070)
	23 to 24	1725 (96)	1855 (96)	2.32 (.027)
	29 to 30	1455 (85)	1628 (90)	4.89 (< .001)
	35 to 36	1357 (69)	1584 (68)	5.93 (< .001)
Speed				
	5 to 6	2819 (176)	2654 (141)	2.15 (.039)
	11 to 12	2146 (107)	2230 (114)	1.39 (.173)
	17 to 18	1783 (86)	1927 (91)	2.84 (.008)
	23 to 24	1609 (94)	1736 (88)	2.46 (.020)
	29 to 30	1447 (71)	1569 (71)	3.84 (< .001)
	35 to 36	1316 (61)	1445 (74)	3.15 (.004)

Note. M = mean; SE = standard error.

If retrieval was completely obligatory, response times for repeated items should be unaffected by the presence of novel items, but this was not the case. If anything, MBP theories of automaticity would predict that response times for repeated items should be faster for each next block because participants have one more instance stored in memory for repeated items in novel blocks than in preceding blocks. Particularly, the pattern is most striking for the speed group, as their goal should be influencing them to use retrieval for all repeated items.

Test Session. To revisit, the secondary question concerns the extent to which differential involvement of retrieval during practice has consequences for later performance. Despite the evidence that the accuracy group used retrieval less than the speed group during practice, the two groups did not differ in response times for repeated items during the first block of test, $t(63) = .44$, $p = .66$. These results are consistent with Logan and Klapp (1991).

INTRODUCTION EXPERIMENT 2

Concerning our primary question, the results of Experiment 1 suggest that participants partially control the involvement of memory retrieval during skill acquisition based on performance goals. However, effects were somewhat modest. One possible explanation could be that some participants of the accuracy group did not associate the instructions to be as accurate as possible with use of the algorithmic process. Thus, although their performance goal was to answer the AA problems accurately, they may not have used the algorithm to do so.

The goal of Experiment 2 was to use a stronger instructional manipulation to yield stronger effects. In Experiment 2, participants were again instructed to answer either as accurately as possible or as quickly as possible. However, unlike Experiment 1, participants in the accuracy group were further instructed that use of the algorithm was the best way to answer as accurately as possible and that they should try to use the algorithm on every trial during practice. Participants in the speed group were further instructed that use of memory retrieval was the best way to answer as quickly as possible and that they should try to use retrieval as soon as possible on every trial. During test, all participants were instructed to answer as fast as possible and told that the best way to do this was to retrieve answers from memory. Given that all other methods of Experiment 2 were the same as Experiment 1, the predictions for Experiment 2 were the same as for Experiment 1.

METHOD EXPERIMENT 2

Participants and Design

Seventy-eight undergraduates from Kent State University completed the experiment in exchange for research credit in an introductory psychology class. Participants were randomly assigned to one of two practice groups, defined by the instructions given to participants regarding their primary goal in practice (accuracy or speed).[2]

Materials and Procedure

Experimental stimuli consisted of the same 120 AA problems used in Experiment 1. The primary manipulation occurred at the beginning of the practice session when participants read instructions. In each group, participants first read instructions explaining the AA verification task and were given examples of true and false problems. All participants were also given instructions regarding the two primary strategies for answering AA verification problems, counting and retrieval. For the accuracy group, participants then read instructions stating that the best way to be accurate is to use the algorithm throughout practice (for complete instructions, see Appendix A, Figure A1). For the speed group, participants then read instructions stating that the best way to be as fast as possible is to use memory retrieval (see Appendix A, Figure A2). During test, all

[2] Due to experimenter error, twice as many participants were randomly assigned to the speed group than to the accuracy group. However, the error does not cause interpretation difficulties because participants were still randomly assigned to groups.

participants were given instructions to use the retrieval process, similar to instructions given to the speed group during practice. All other aspects of Experiment 2 were identical to Experiment 1.

Results

Data for four participants were dropped from analyses because of performance below 75% accuracy in either the practice or test session. Accuracy was near ceiling throughout the experiment, with differences in accuracy approaching significance during practice between the count group (M =94.4%, SE = 1.1) and the retrieve group (M = 91.5%, SE = 0.9), $t(72) = 1.93$, $p = .06$. During test, accuracy was not significantly different between the acuracy group (M = 94.1%, SE = 0.7) and the speed group (M = 93.1%, SE = 0.7), $t(72) = 0.82$, $p = .41$. Analyses of response times were conducted on correct response trials only (excluding response times less than 50 ms and greater than 9000 ms, < 1% of trials). Raw response times were again log transformed, averaged over trials for each participant, and then individual averages were anti-log transformed as in Experiment 1.

For each participant, response times for the 12 repeated items were averaged for each block of practice and for each block of test. Similarly, for blocks containing novel items, response times for the 12 novel items were averaged. Mean response times for repeated and novel items in each group for each block are presented in Figure 2.

Below, results are reported in the same manner as in Experiment 1, with practice session data reported first, followed by test session data.

Practice Session. Concerning Prediction 1, an inspection of Figure 2 indicates that response times were slower for novel items than for repeated items in both groups. A 2 (item: repeated, novel) X 2 (group: accuracy, speed) mixed factor ANOVA resulted in a significant main effect of item type, $F(1,72) = 249.53$, MSE = 180982, $p < .001$, and a main effect of group that approached significance, $F(1,72) = 3.27$, MSE = 898651, $p = .08$. The group X item interaction was not significant, $F(1,72) = 1.74$, $p = .19$. Thus, the accuracy group did not completely avoid the use of retrieval.

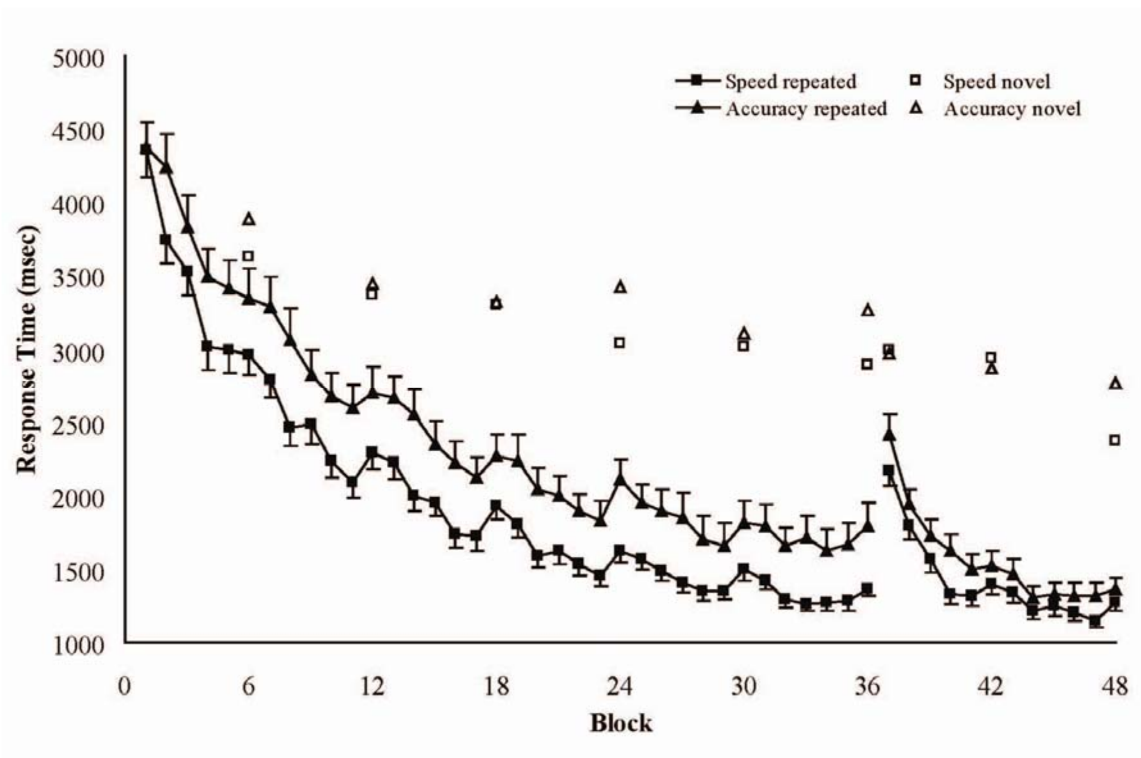

Figure 2. Experiment 2 mean response times as a function of performance goal group, blocks of trials, and experimental session. Response times are further separated into novel-item and repeated items blocks, where applicable in practice and test sessions.

Concerning Prediction 2, an inspection of Figure 2 indicates that response times for repeated items were slower for the accuracy group than for the speed group. A 2(group: accuracy, speed) X 36(block) mixed factor ANOVA resulted in a significant main effect of group and a significant main effect of block, $F(1,72) = 6.79$, MSE = 14338592, $p = .01$ and $F(35,2520) = 206.89$, MSE = 188349, $p < .001$ respectively. The group X block interaction was not significant, $F < 1$. Follow up 1-tailed *t*-tests revealed that response times for repeated items were slower for the accuracy group than for the speed group almost entirely throughout practice (blocks 5, 6, and 9 approached significance, *t*s > 1.45, *p*s < .08; blocks 4, 7-8, and 10-36 were significantly different, *t*s > 1.76, *p*s < .04), which is consistent with the possibility that the accuracy group was at least partially successful in controlling the involvement of memory retrieval.

Concerning Prediction 3, an inspection of Figure 2 indicates that response times for repeated items were greater in blocks containing novel items than preceding blocks (see Table 2 for results of inferential statistics), which is inconsistent with MBP theories' assumption of obligatory retrieval.

Test Session. Concerning the extent to which differential involvement of retrieval during practice has consequences for later performance, response times for repeated items during the first block of test were not significantly different between groups, $t(72) = 1.45$, $p = .08$, consistent with results from Logan and Klapp (1991).

Table 2: Experiment 2 response times for repeated items: Blocks with novel items present versus preceding blocks.

Group	Comparison Blocks	Preceding Block M (SE)	Novel Block M (SE)	*t*-test Value (Sig.)
Accuracy				
	5 to 6	3413 (190)	3346 (204)	0.63 (.535)
	11 to 12	2592 (164)	2704 (181)	1.29 (.210)
	17 to 18	2124 (135)	2268 (152)	2.10 (.046)
	23 to 24	1831 (131)	2112 (137)	3.99 (.001)
	29 to 30	1661 (151)	1815 (145)	2.81 (.010)
	35 to 36	1664 (150)	1790 (156)	1.83 (.079)
Speed				
	5 to 6	2994 (154)	2966 (142)	0.45 (.657)
	11 to 12	2089 (108)	2286 (110)	4.66 (< .001)
	17 to 18	1722 (100)	1933 (93)	3.75 (< .001)
	23 to 24	1453 (72)	1622 (78)	4.28 (< .001)
	29 to 30	1357 (64)	1494 (71)	4.35 (< .001)
	35 to 36	1279 (67)	1362 (50)	2.26 (.029)

Note. M = mean; SE = standard error.

INTRODUCTION EXPERIMENT 3

Experiment 2 provided a stronger manipulation than Experiment 1, with response times for repeated items in almost every block of practice significantly faster for the speed group than for the accuracy group (except for initial blocks, which were not expected to differ). Indeed, all patterns of results for Experiment 2 were qualitatively the same as Experiment 1, only stronger. Concerning the primary question of interest, the results of Experiments 1 and 2 suggest that retrieval may not be obligatory and that participants exert at least partial control over the involvement of retrieval during skill acquisition based on their performance goals.

However, an alternative interpretation is that manipulating task instructions to influence performance goals had no effect on participants' ability to inhibit the involvement of memory retrieval. Rather, participants in the accuracy group may still have retrieved answers from memory, but because instructions recommended using the algorithm on every trial, they chose to ignore retrieved answers and continued to use the algorithm. Such a possibility was noted by Logan (1988) and allows for retrieval to still be obligatory.

To evaluate this alternative interpretation, in Experiment 3, participants were probed for type of process used during practice. Process report options included retrieval, counting, and retrieved but then counted (discussed further below). If participants can control the involvement of retrieval during practice, reported retrieval use during practice will be greater for the speed group than for the accuracy group (excluding beginning blocks because both groups must use the algorithm). Alternatively, if retrieval is obligatory but participants of the accuracy group ignore retrieved information, total reported retrieval use (retrieve only probe + retrieve then count probe) would not significantly differ between the accuracy and speed groups. However, if participants are able to partially control the involvement of memory retrieval during skill acquisition, total reported retrieval use during practice would be significantly greater for the speed group than for the accuracy group.

Including process probes in Experiment 3 also permits further analysis of other effects. Regarding presenting novel items, if participants control the use of retrieval during skill acquisition, reported retrieval use for repeated items will be less in blocks with novel items than in preceding blocks without novel items. However, an alternative account is that retrieval use for repeated items does not change but instead speed of retrieval for repeated items is slowed due to switch costs. *Switch cost* refers to a response time increase for a given trial when the process used on a previous trial is different versus when the process performed on a previous trial is the same (e.g., Koch & Allport, 2006; Logan & Bundesen, 2003; Meiran, 1996; Rogers & Monsell, 1995; Yeung, 2010). If this alternative interpretation is correct, reported retrieval use for repeated items will not significantly differ between novel blocks and preceding blocks without novel items. Rather, response times for repeated items reported retrieved will be slower for novel blocks than for preceding blocks without novel items.

Regarding the secondary question of interest, results of Experiments 1 and 2 suggest that differential involvement of memory retrieval during practice has no consequence for later performance. However, alternatively, similar overall response times for the two groups during the first block of test may have reflected trade offs between likelihood of retrieval and speed of retrieval in the two groups. If this is the case, reported retrieval use during the first block of test would be significantly different between the two groups and response times for items reported retrieved would be significantly different between the two groups.

METHOD EXPERIMENT 3

Participants and Design

Fifty-five undergraduates from Kent State University completed the experiment in exchange for research credit in an introductory psychology class. Participants were randomly assigned to one of two groups, accuracy or speed.

Materials and procedure

Experimental stimuli were the same 120 AA items from Experiments 1 and 2.

Procedures were identical to Experiment 2 with the following exceptions. At the beginning of practice, after reading instructions for how to answer AA verification problems, participants were instructed that they would be probed for type of process used. Four types of process probe options were explained (count only, retrieval only, retrieved then counted, and other). Participants were instructed to use the ‘count only’ option when they only counted to solve the AA problem. Participants were instructed to use the ‘retrieve only’ option when they only retrieved the answer from memory. Participants were instructed to use the ‘retrieve then count’ option when they first successfully retrieved the answer from memory, but then completed counting to check their retrieved answer. Participants were instructed to use the ‘other’ option when they used a strategy other than the three previously described (see Appendix B for complete probe instructions).

Half of all repeated items and novel items were probed for type of process use, with the same subset of repeated items probed in each block of practice and test. On probe trials, if the response to the AA problem was correct, the response buttons and AA problem disappeared and were immediately replaced by four strategy probe buttons ("COUNT ONLY", "RETRIEVE ONLY", "COUNT THEN RETRIEVE", and "OTHER"). If the response was incorrect, the response buttons and AA problem disappeared and were immediately replaced by a red "ERROR" message presented for 1000 ms, followed by the strategy probe buttons. Upon pressing one of the strategy probe buttons, the probe buttons disappeared, replaced by a "next" button. The participant clicked on the "next" button to present the orientation stimulus for the next problem (see Experiment 1 procedure).

Results

Data for four participants were dropped from analyses because of performance below 75% accuracy. During practice, accuracy was significantly greater for the count group (M = 95.6%, SE = 0.7) than for the retrieve group (M = 92.0%, SE = 1.2), $t(49) = 2.64$, $p = .01$. During the test session, accuracy did not significantly differ for the count group (M= 94.1%, SE = 1.2) and the retrieve group (M = 94.5%, SE = 1.1), $t(49) = 0.25$, $p = .80$. Analyses of response times were conducted on correct response trials only (excluding response times less than 50 ms and greater than 9000 ms, < 1% of trials). The log transformation procedure was the same as in Experiments 1 and 2.

For each participant, response times for the 12 repeated items were averaged for each block of practice and for each block of test. Similarly, for blocks containing novel items, response times for the 12 novel items were averaged. Mean response times for repeated practice and novel items in each group for each block are presented in Figure 3. Results replicating Experiments 1 and 2 will be presented first, followed by process probe results.

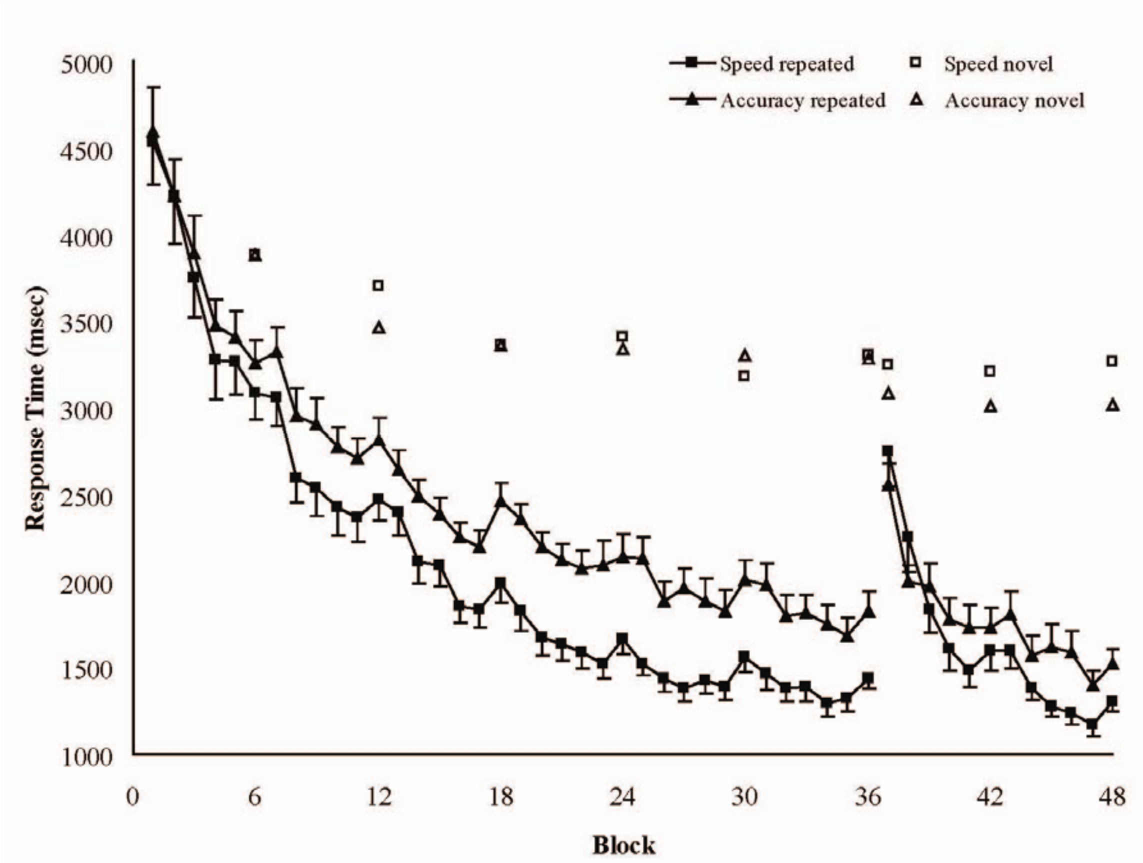

Figure 3. Experiment 3 mean response times as a function of performance goal group, blocks of trials, and experimental session. Response times are further separated into novel-item and repeated items blocks, where applicable in practice and test sessions.

Practice Session. For Prediction 1, a 2 (item: practice, novel) X 2 (group: accuracy, speed) mixed factor ANOVA resulted in significant main effects of item, $F(1, 49) = 206.98$, MSE = 189068, $p < .001$. Although the main effect of group was not significant [$F(1, 49) = 1.44$], the group X item interaction was significant, $F(1,49) = 5.81$, MSE = 189068, $p = .02$. The results suggest that although the accuracy group did not completely avoid the use of retrieval, the difference in response times for repeated items and novel items was less for the accuracy group than for the speed group.

For Prediction 2, a 2(group: accuracy, speed) X 36(block) mixed factor ANOVA resulted in significant main effects of group and block, $F(1,49) = 7.41$, MSE = 8922708, $p = .009$ and $F(35,1715) = 143.68$, MSE = 231831, $p < .001$ respectively. The group X block interaction was not significant, $F(35,1715) = 1.27$, $p = .13$. Follow up 1-tailed *t*-tests comparing response times for repeated items separately for each block of practice revealed that response times for repeated items were consistently greater for the count group than for the retrieve group almost entirely throughout practice (blocks 9-11 approached significance, *t*s > 1.41, *p*s < .08; blocks 12 and 14-36 were significantly different, *t*s > 1.73, *p*s < .05), replicating the results of Experiment 2.

For Prediction 3, an inspection of Figure 3 indicates that response times for repeated items were greater in blocks containing novel items than preceding blocks (see Table 3), replicating results of Experiment 2.

Test Session. Concerning the extent to which differential involvement of retrieval during practice has consequences for later performance, response times for repeated items during the first block of test were not significantly different between groups, $t(49) = 0.91$, $p = .37$, consistent with the results of Experiments 1 and 2.

Table 3: Experiment 3 response times for repeated items: Blocks with novel items present versus preceding blocks.

Group	Comparison Blocks	Preceding Block M (SE)	Novel Block M (SE)	*t*-test Value (Sig.)
Accuracy				
	5 to 6	3469 (139)	3340 (133)	1.57 (.129)
	11 to 12	2766 (120)	2885 (132)	1.89 (.071)
	17 to 18	2253 (99)	2492 (95)	3.04 (.006)
	23 to 24	2125 (141)	2155 (135)	0.48 (.635)
	29 to 30	1872 (125)	2090 (117)	3.02 (.006)
	35 to 36	1771 (123)	1833 (106)	0.79 (.440)
Speed				
	5 to 6	3282 (185)	3127 (158)	1.41 (.170)
	11 to 12	2469 (171)	2550 (141)	0.91 (.370)
	17 to 18	1899 (118)	2040 (118)	3.45 (.002)
	23 to 24	1547 (88)	1663 (79)	1.52 (.142)
	29 to 30	1386 (70)	1571 (81)	3.96 (.001)
	35 to 36	1328 (74)	1443 (60)	2.25 (.034)

Note. M = mean; SE = standard error.

Process probes. Data for 12 participants were removed from all strategy report analyses due to variance of strategy report less than 10%, an indication that the participants may have been simply responding in a manner they thought would appear to comply with task instructions rather than accurately reporting process use. The ‘other’ probe option was used sparingly by participants and thus is not reported. Response rates for other three options are presented in Figure 4.

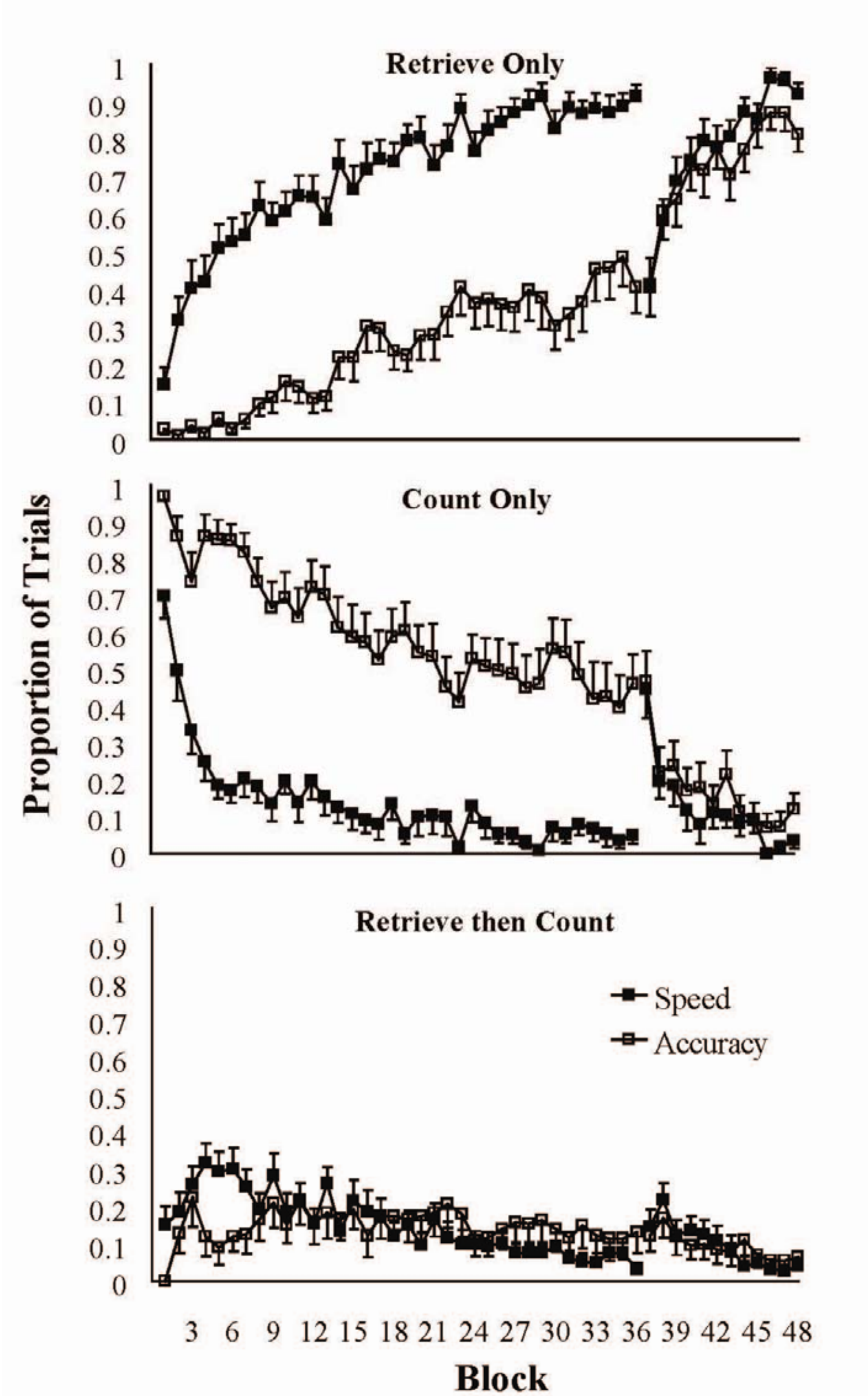

Figure 4. Experiment 3 proportion of total trials as a function of blocks of trials and experimental session for 'retrieval only', 'count only', and 'retrieve then count' process options. Values are only for repeated items.

If participants are able to partially control the involvement of memory retrieval during practice, reported retrieval use would be greater for the speed group than for the accuracy group (except at the beginning of practice where all participants must count). An inspection of Figure 4 indicates that proportion of repeated items retrieved was greater for the speed group than for the accuracy group. A 2(group: accuracy, speed) X 36(block) mixed factor ANOVA resulted in significant main effects of block and group, $F(35,1295) = 30.20$, MSE = .034, $p < .001$ and $F(1,37) = 76.83$, MSE = .976, $p < .001$ respectively. The group X block interaction was also significant, $F(35,1295) = 1.90$, MSE = .034, $p = .001$. For both groups, reported retrieval use increased with practice, with the increase in reported retrieval use greater for the speed group than for the count group. The results are consistent with the idea that participants are able to partially control the use of memory retrieval during skill acquisition.

Alternatively, if retrieval is obligatory and not under participant control, the groups should not differ in total reported retrieval use (retrieve only option + retrieve then count option). This was not the case. A 2(group: accuracy, speed) X 36(block) mixed factor ANOVA resulted in significant main effects of block and group, $F(35,1295) = 22.36$, MSE = .033, $p < .001$ and $F(1,37) = 51.01$, MSE = 1.487, $p < .001$ respectively. The group X block interaction was also significant, $F(35,1295) = 2.37$, MSE = .033, $p < .001$. Most important, across practice, total reported retrieval use was greater for the speed group than for the accuracy group, inconsistent with the idea that the accuracy group was ignoring obligatorily retrieved answers.

Concerning the alternative novel item effect on repeated items, if switch costs occurred in blocks with novel items but not in preceding blocks without novel items, reported retrieval use for repeated items would not significantly differ between blocks with novel items and preceding blocks without novel items for either group. However, an inspection of Table 4 indicates that proportion of repeated items reported retrieved was less in blocks with novel items than preceding blocks without novel items.

Table 4: Experiment 3 response times for and proportion of repeated-items reported retrieved in blocks with novel items and preceding blocks without novel items.

Group	Proportion		Response Time	
	Preceding Block M (SE)	Novel Block M (SE)	Preceding Block M (SE)	Novel Block M (SE)
Accuracy	.30 (.04)	.24 (.04)	1506 (86)	1533 (90)
Speed	.77 (.04)	.74 (.04)	1616 (79)	1707 (83)

Note. For Proportion, values are proportion of repeated items reported retrieved. For Response Time, values are in milliseconds. Standard errors are in parentheses.

A 2(group: accuracy, speed) X 2(block: novel, preceding) mixed factor ANOVA resulted in significant main effects of block and group, $F(1,37) = 10.88$, MSE = 0.003, $p = .002$ and $F(1,37) = 82.37$, MSE = 0.056, $p < .001$. Proportion of repeated items retrieved was greater for the speed group (M = .75, SE = .04) than for the count group (M = .27, SE = .04). Importantly, proportion of repeated items retrieved was less for novel blocks (M =

.49, SE = .03) than for preceding blocks without novel items (M = .53, SE = .03), inconsistent with the idea that switch costs occurred during blocks with novel items. The interaction between group and block was not significant, $F(1,37) = 1.18$, consistent with the idea that the accuracy group exerted partial control over the use of memory retrieval. In addition, if switch costs occurred in blocks with novel items but not in preceding blocks without novel items, response times for repeated items reported retrieved would be slower for novel blocks than for preceding blocks without novel items. This pattern of results did not occur (see Table 4). A 2(group: accuracy, speed) X 2(block: novel, preceding) mixed factor ANOVA resulted in no significant main effects or interactions, Fs < 2.73, *p*s $> .11$, inconsistent with the idea that switch costs occurred in blocks with novel items.

Finally, concerning the secondary question, if overall response times for repeated items in the first block of test represent a likelihood of retrieval/speed of retrieval trade off between the two groups, reported retrieval use for the first block of test would be significantly different between the two groups. An inspection of Table 5 indicates that reported retrieval did not significantly differ between the two groups.

Table 5: Experiment 3 response times and proportion of strategy use for repeated items by process option for the first block of test.

	Proportion		Response Time	
	Accuracy	Speed	Accuracy	Speed
Retrieve Only	.41 (.08)	.41 (.08)	1984 (181)	2141 (224)
Count Only	.47 (.08)	.45 (.08)	3673 (381)	3661 (390)
Retrieve then Count	.12 (.04)	.15 (.05)	2472 (376)	3579 (383)

Note. For Proportion, values are proportion of total trials responded to with each type of process option. For Response Time, values are in milliseconds. Standard errors are in parentheses.

For the first block of test, a *t*-test examining the proportion of repeated items retrieved between the accuracy and speed groups resulted in no significant difference, $t(37) = 0.04$, inconsistent with the occurrence of a speed accuracy trade off. In addition, if a speed/accuracy trade off occurred between the two groups, response times for repeated items reported retrieved would be significantly different between the groups. However, see Table 5. For the first block of test, a *t*-test examining the response times for repeated items reported retrieved resulted in no significant difference between the two groups, $t(27) = 0.53$, inconsistent with the occurrence of a speed accuracy trade off.

Together, the results of analyses for proportion of repeated items retrieved and for response times of repeated items retrieved during the first block of test suggest that there are no consequences for differential retrieval use during practice on later performance, consistent with Logan and Klapp (1991).

GENERAL DISCUSSION

Of primary interest, the present research further established that learners can control the involvement of retrieval during skill acquisition by setting a performance goal. Learners were able to partially control the involvement of memory retrieval during skill acquisition in each of the three experiments. Two key results suggested partial control of the involvement of memory retrieval. First, response times for repeated items during practice were slower for the accuracy groups than for the speed groups. Second, response times for repeated items were slower in blocks with novel items than in preceding blocks without novel items.

Although the key results were consistent with the idea that individuals partially control the involvement of memory retrieval during skill acquisition, an alternative account posited that retrieval was obligatory, but individuals chose to ignore retrieved information and continued to count based on their performance goal. Process probe results in Experiment 3 ruled out this alternative interpretation. Total repeated items reported retrieved (retrieve only option + retrieve then count option) was greater for the speed group than for the accuracy group.

The current research adds to the small number of studies examining the extent to which participants can control the involvement of memory retrieval during skill acquisition. Relative to prior research (Bourne et al., 2010; Reder & Ritter, 1992; Touron

& Hertzog, 2004), the current study showed that individuals' performance goals for a task can affect the extent to which they control the involvement of retrieval use during skill acquisition. The current research also showed that manipulating task instructions can influence individuals' performance goals.

Of secondary interest, the present research also examined the consequences of differential process use during practice on later performance. Results suggested that differential process use during practice did not affect later performance, consistent with the results of Logan and Klapp (1991, Experiment 4). Response times for repeated items in the first block of test were not significantly different between the accuracy groups and the speed groups. Probe results suggested that there were no offsetting effects of differential memory retrieval during practice.

Although the current studies replicate Logan and Klapp (1991, Experiment 4) and suggest that there are no consequences of differential involvement of memory retrieval during practice on later performance, at least one alternative explanation still remains. Given that accuracy groups were instructed to use the algorithm on each trial of practice and then asked to retrieve from memory during test, participants in the accuracy group may have perseverated using the algorithm during test. If this alternative interpretation is correct, for each current experiment, reported retrieval use during the first block of test may have underestimated the number of total items that the accuracy group could actually retrieve. Thus, overall response times for repeated items during the first block of test for each experiment may have overestimated the accuracy groups' true aggregate response times. A proposal for a study examining this possibility will be discussed below in Future Directions.

Implications for Memory-Based Processing Theories of Automaticity

To date, MBP theories of automaticity that (Logan, 1988; Palmeri, 1997) offer no mechanism for top-down control of the involvement of memory retrieval during skill acquisition. Rather, retrieval is assumed to be obligatory, with the speed of retrieval only being related to the number of instances stored in memory for a given stimulus and the likelihood of retrieval being related to the relative speed of the algorithm. Given that results of the current experiments suggest that individuals can control the involvement of memory retrieval during skill acquisition, instance based MBP theories of automaticity need to be further instantiated to include a mechanism for top-down control.

As is, Logan’s (1988) instance theory is not able to be easily altered to include a mechanism for top-down control of retrieval during skill acquisition. However, one assumption of Palmeri’s exemplar-based random walk theory (EBRW, 1997) could be altered in order to account for individuals’ control of retrieval during skill acquisition. Unlike Logan’s instance theory, in EBRW, retrieval does not win the race with the algorithm when one trace is retrieved from memory before the algorithm completes. Instead, for retrieval to win the race with the algorithm, many traces must be retrieved from memory. In EBRW, each time a trace is retrieved, evidence is accumulated towards a threshold for responding from memory. Once enough traces have been retrieved from memory to accumulate enough evidence to reach the threshold for responding, a retrieval response is made. However, if the algorithm completes before enough traces are retrieved from memory, the algorithm is used to respond.

Key here is the assumption that a threshold must be reached before a retrieval response will occur. One way a top-down control mechanism can be added to EBRW (Palmeri, 1997) is to allow individuals to be able to adjust the threshold for retrieval. If individuals can adjust this threshold, either by evaluating the costs and benefits of the retrieval process for a given task (Touron & Hertzog, 2004) or by adopting a performance goal for a task (current research), the amount of evidence (number of traces retrieved) required to respond using retrieval can be adjusted. As in Logan's (1988) instance theory, in EBRW (Palmeri, 1997), speed of retrieval for a specific memory-trace is stochastic. Thus, if individuals can adjust the threshold for retrieval, the speed at which a retrieval response is made would depend on the number of traces required to be retrieved and on the sum of the speed of retrieval for each specific trace.

In sum, the current research added to the small number of previous studies that suggest that participants have partial control of memory retrieval during skill acquisition. Current instance based MBP theories of automaticity have no top-down control mechanism to account for the present findings. Thus, instance based MBP theories of automaticity need to be further instantiated in order to account for the findings that individuals can partially control memory retrieval.

FUTURE DIRECTIONS

Given that the present research is one of a small number of studies that suggest that participants have partial control over memory retrieval during skill acquisition, future research is needed to further explore factors that influence the involvement of memory retrieval during skill acquisition (individual differences, including working memory capacity could be one option).

As mentioned in earlier, an alternative explanation for the results of no performance differences in test is that participants of the accuracy group are perseverating using the algorithm, rather than performing as instructed and using memory retrieval. One way to examine this possibility is to conduct an experiment with methods similar to Experiment 3. The key methodological difference between Experiment 3 and the proposed experiment occurs during test. Rather than present previously practiced items immediately at the beginning of test, a second set of items would be repeatedly presented for 12 blocks at the beginning of test. After 12 test blocks containing the second set of items, participants would then be presented with the previously repeated items from practice. Repeatedly presenting a second set of items at the beginning of test would allow participants who perseverate using the algorithm to change their task goals. Thus, by eliminating perseveration before previously practiced items are presented, response times for repeated items during test should give an accurate measure indicating whether there are consequences of differential involvement of memory retrieval during practice.

Although not directly related to the question of the extent to which individuals control the involvement of retrieval during skill acquisition, future research needs to make clear distinctions between task factors that influence the involvement of memory retrieval during skill acquisition and participant factors that influence the involvement of retrieval during skill acquisition. For example, it is likely that Bourne et al.'s (2010) results for target-cue position represent a task characteristic that influences the involvement of memory retrieval. Retrieval use is greater for targets at the end of the stimulus than at the beginning of the stimulus because of the differences in algorithm speeds, not because participants differ in the value they give to use of the algorithm. Future research should manipulate algorithm speed in a systematic way to examine the task influence over the involvement of memory retrieval. One way in which this could be done is to vary arithmetic stimuli according to the number of algorithmic steps required to answer each problem. Research such as this could offer valuable insight towards how to develop training schedules that afford the largest gains with the least effort.

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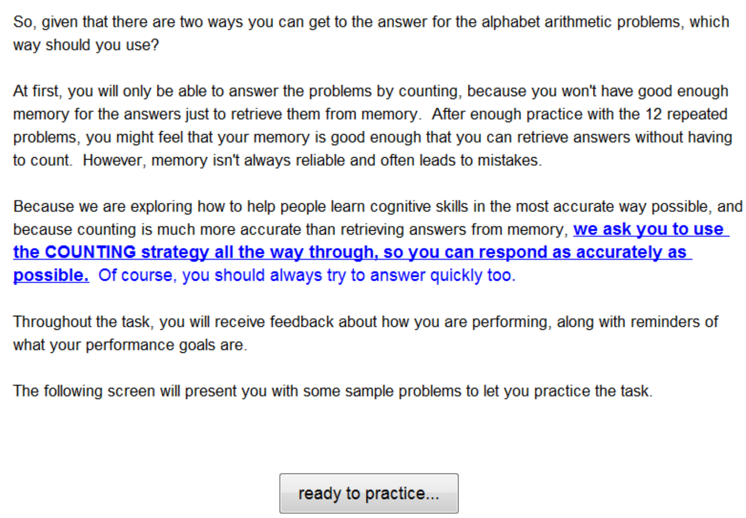
APPENDIX A

PRACTICE INSTRUCTIONS EXPERIMENT 2



So, given that there are two ways you can get to the answer for the alphabet arithmetic problems, which way should you use?

At first, you will only be able to answer the problems by counting, because you won't have good enough memory for the answers just to retrieve them from memory. After enough practice with the 12 repeated problems, you might feel that your memory is good enough that you can retrieve answers without having to count. However, memory isn't always reliable and often leads to mistakes.

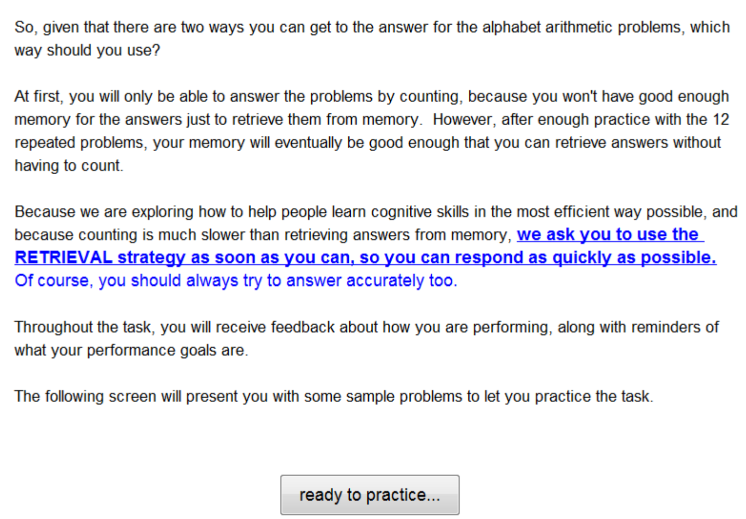
Because we are exploring how to help people learn cognitive skills in the most accurate way possible, and because counting is much more accurate than retrieving answers from memory, **we ask you to use the COUNTING strategy all the way through, so you can respond as accurately as possible.** Of course, you should always try to answer quickly too.

Throughout the task, you will receive feedback about how you are performing, along with reminders of what your performance goals are.

The following screen will present you with some sample problems to let you practice the task.

ready to practice...

Figure A1. Experiment 2 practice instructions for accuracy group.



So, given that there are two ways you can get to the answer for the alphabet arithmetic problems, which way should you use?

At first, you will only be able to answer the problems by counting, because you won't have good enough memory for the answers just to retrieve them from memory. However, after enough practice with the 12 repeated problems, your memory will eventually be good enough that you can retrieve answers without having to count.

Because we are exploring how to help people learn cognitive skills in the most efficient way possible, and because counting is much slower than retrieving answers from memory, **we ask you to use the RETRIEVAL strategy as soon as you can, so you can respond as quickly as possible.** Of course, you should always try to answer accurately too.

Throughout the task, you will receive feedback about how you are performing, along with reminders of what your performance goals are.

The following screen will present you with some sample problems to let you practice the task.

ready to practice...

Figure A2. Experiment 2 practice instructions for speed group.

APPENDIX B

PROCESS PROBE INSTRUCTIONS EXPERIMENT 3

In addition to solving "alphabet arithmetic" problems, you will sometimes be asked how you solved a problem. When asked for how you solved a problem, the screen will look like this:

Strategy?

RETRIEVAL ONLY | COUNT ONLY | RETRIEVE THEN COUNT | OTHER

RETIEVAL ONLY - Press this button when you used **ONLY** the **RETRIEVAL** strategy.

COUNT ONLY - Press this button when you used **ONLY** the **COUNTING** strategy.

RETRIEVE THEN COUNT - Press this button **ONLY** when you first **RETRIEVED** the answer and then completed the **COUNTING** strategy. You would **NOT** press this button if you counted first and then retrieved, if you tried to retrieve but couldn't and then counted, or some other combination of these two strategies. Only press it if you successfully retrieved the answer and then went ahead and counted after that (for example, to check your answer).

OTHER - Press this button **ONLY** if you used some other strategy or combination of strategies not accounted for by the other buttons.

next

Figure B. Experiment 3 participant instructions for process probe.