Examining the Effectiveness of Retrieval-based Learning Strategies in First Generation College Students

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Abstract

Retrieval-based learning activities involve actively bringing information to mind. Previous research has shown this to be an effective way to produce meaningful learning. This research investigated the efficiency of this strategy amongst first-generation college students. Twenty-eight students were recruited from the Preparatory Enrollment Program (PEP) at Rhode Island College. In this within-subjects experiment, students participated in two learning activities, counterbalanced for order. Students learned two texts. With one text, they engaged in a retrieval-based learning activity by actively recalling as much information as they could remember and writing it down. With the other text, they simply read. Students completed reading comprehension and speed of processing tests. Then, they answered short-answer questions about the texts to assess how much they learned. Lastly, they filled out surveys to provide information about how they typically study. The results indicated that retrieval-based learning strategies did not produced any meaningful learning compared to the control. Additionally, speed-of-processing abilities have no interaction with the learning condition, however those who performed higher on the reading comprehension task did perform better in the final assessment. When making judgments about the learning activities, students found free recall to be more difficult than the control. Lastly, about half of the students report using retrieval in some way during their own studying, but they still report more use of rereading.

Examining the Effectiveness of Retrieval-based Learning Strategies in First Generation College Students

Retrieval practice, or actively bringing information to mind, has been shown to lead to improved long-term retention relative to other study strategies typically used by college students (repeated reading, see Roediger & Karpicke, 2006a for a review). Most importantly, retrieval practice has been shown to promote meaningful learning in addition to learning fact-based information (Smith, Blunt, Whiffen, & Karpicke, 2016). Most of the work on retrieval-based learning has been done with college students, and typically the students tested are from high-performing Research 1 institutions. With these students, simply requiring them to put their text materials away and write out everything they know (i.e., free recall) can be very helpful. This strategy also has the added benefit of being very easy to implement with students as instructions are minimal.

However, does this strategy work for all students? More recent research has begun to investigate the effectiveness of retrieval-based learning strategies with elementary students. However, some research has found that standard retrieval-based learning activities, such as free recall, are not effective with these populations (Karpicke, Blunt, Smith, & Karpicke, 2014). With these students, the retrieval-based learning activity needed to be modified in order to ensure success. The purpose of the present research is to examine whether standard retrieval-based learning strategies, such as free recall, will help improve meaningful learning in college students who may not be as strong academically. For example, first-generation college students are often at a disadvantage when they enter college and may need more help to guide their independent learning. Before recommending that these students simply engage in free recall, we first need to know whether retrieval-based learning strategies that tend to work well with other college

students, also improve learning with these students. We first review the literature on retrieval practice and meaningful learning, individual differences, and metacognition, and then report an experiment testing the effectiveness of retrieval-based learning, with first-generation college students.

Retrieval Practice and Meaningful Learning

Previous research has shown that actively recalling information improves learning. Roediger and Karpicke (2006b) investigated the effects of testing under an educational context. They compared students' test performance when they either studied the material multiple times or did free-recall tests immediately after reading the passage. In their first experiment, students either took a test or studied again before the final test which occurred either five minutes, two days, or one week later. In Experiment 2, students did one of the following three: read a passage once and took three tests, studied three times and took one test or studied the passages four times and took a final test. Results showed that immediate testing after reading led to better long-term retention than repeatedly studying the passage. These results demonstrate that actively bringing information to mind improves long-term memory for that information. Based on this research and others, cognitive psychologists conclude that education should include many practice tests and quizzes. Furthermore, students can use retrieval practice, such as practice quizzes or simply writing out everything they can remember about a topic, to improve their own independent learning in their courses.

When investigating the benefits of retrieval practice, some studies have also analyzed if testing format matters and which is more beneficial. Kang, McDermott and Roediger (2007), examined the effect of testing format on long-term retention by conducting two identical experiments; the only difference was that the second experiment included corrective feedback

after testing. In the first session of both experiments, participants read four different passages and after each, they were given either an SA test, MC test, statements that included main ideas of the passage they had just read or a filler questionnaire. The second session occurred three days later during which students answered test questions in both MC and SA formats on the previously read passages. The results of the first experiment showed that regardless of the testing format of the final test, students scored higher when they had MC as an initial testing format. The second experiment was very similar to the first, but this time the students received corrective feedback after answering each question. The results showed that the SA initial tests had more of an effect on both of the final tests than the initial MC test; this indicates that there is a positive effect of SA tests when given corrective feedback. However, more recent research (McDermott, Agarwal, D'Antonio, Roediger & McDaniel, 2014; Smith & Karpicke, 2014) suggests that short-answer and multiple-choice questions both improve long-term retention, and differences between the effectiveness of the two formats are very small. This research points to the importance of actively retrieving information, achieving reasonable success, and providing feedback to correct errors to improve learning using any question format.

The retrieval-based learning activities most typically studied involve practice tests or quizzes; however, what is important is the act of bringing information to mind, not the test per se. For example, Blunt and Karpicke (2014) investigated the effectiveness of concept mapping as a retrieval practice method as opposed to recalling in paragraph form. Concept mapping is a visual-spatial way to represent information, specifically focusing on the relationships between topics or ideas. To create a concept map, students draw circles with concepts or ideas in the center. They then draw links to connect the concepts and write the nature of the relationship on the link. For examples, see Blunt and Karpicke (2014). The study was composed of two

experiments. In the first experiment, the undergraduate students were randomly assigned to groups and were either in the concept map retrieval condition or the paragraph retrieval condition. First, students read a text. Then, those in the concept map condition, had to retrieve the information from memory, in order to create the concept map. In the paragraph condition, the students brought the information to mind and wrote out what they could remember. They were then tested a week later, and the results showed that the two different strategies were equivalent in terms of learning. In the second experiment, the same procedure was applied except that there were two additional conditions creating a 2x2 factorial design. The students had to either create a concept map or write the information in paragraph form, and they either did this while they still had the text in front of them (copying) or without the text (retrieval conditions). All students were tested a week later. The results showed that there was a significant difference between the conditions with the text in front of them and without the text in front of them. Students learned more when they had to produce the information as opposed to being able to reference the text, thus showing that recalling information is the key to producing more learning. The format of the retrieval (paragraph or concept map from memory) did not matter. Other research has shown that the format of retrieval practice does not much matter as well, supporting the conclusion that bringing information to mind is what is important (Little, Bjork, Bjork, & Angello, 2012; Smith & Karpicke, 2014; Smith, Roediger, & Karpicke, 2013).

Much research about retrieval-based learning strategies has been conducted with specifically undergraduate college students (Blunt & Karpicke, 2014; Karpicke & Blunt, 2011; Smith & Karpicke, 2014). The current research seeks to investigate the same questions but in a defined undergraduate student population. Utilizing the Preparatory Enrollment Program (PEP) at Rhode Island College, we get access to a population of academically disadvantaged

undergraduate college students. Those students are first-generation college students and are of low socioeconomic status. The PEP program is dedicated to helping high school students have a seamless transition into college, by guiding them throughout their academic career. Research has shown that it is more difficult for first-generation college students to succeed in a collegiate setting (Stephens, Fryberg, Markus, Johnson, & Covarrubias, 2012). Any research that identifies effective ways for PEP students to guide their independent learning has the potential to help them succeed in college.

The primary purpose of this study was to examine whether study strategies that work well for other college students (e.g., undergraduates at large research institutions) also work for students in the PEP program. This study was an extension of a previous study conducted by Smith, Nunes, and Jensen (2014). It investigated the effectiveness of retrieval-based learning amongst academically disadvantaged high school students that were in the Upward Bound Program. Based on the results we can help PEP accomplish its mission.

Retrieval Practice and Individual Differences

Knowing that retrieval-based learning strategies seem to work well with students overall, researchers have looked into whether individual differences might interact with the effectiveness of retrieval practice as a learning strategy. For example, Karpicke, Blunt, and Smith (2016), looked into the interaction between the impact of retrieval based learning and individual differences in elementary school children. The researchers recruited children in the fourth grade for three experiments of a mixed list, within-subject design. In the three experiments, students studied a list of words, then restudied them or practiced retrieving them. Then they all had a final recall test for Experiments 1 and 2 and a recognition test for Experiment 3. They measured the individual differences by assigning the students a reading comprehension task (Maze reading

comprehension task) and a speed of processing task (Cross-out task). The results overall demonstrated that retrieval practice does enhance learning in children. Additionally, it does so regardless of reading comprehension and speed of processing skills.

Retrieval Practice and Metacognition

Some research suggests that students are not very good at judging their own learning during their independent study (Roediger & Karpicke, 2006b). Thus, while previous research has established that retrieval-based learning strategies are effective at producing learning, at least in some college students, students may not be aware of what strategies work well and what strategies do not. If students cannot accurately judge their own learning, then they may not be very good at selecting effective learning strategies on their own. For example, earlier in this paper, we described two experiments by Roediger and Karpicke (2006b). In the second experiment, the researchers asked how well students could judge their own learning by asking them to predict their performance on the final test. During the first session of the experiment, students either read the passage four times, read the passage three times and practiced retrieval once, or read the passage one time and practiced retrieval three times. Importantly, before leaving the session, students were asked to predict how well they thought they would do on a final test either five minutes later or one week later. Students in the one-week condition thought they would remember just as much as students in the five-minute condition. Students in the repeated reading group predicted that they would perform better on the final test than students in the two retrieval practice conditions. Yet the results from the final test one week later were exactly the opposite. Students who retrieved the information performed better than students who repeatedly read the passage. This shows that students are not aware of the effectiveness of

retrieval practice, and have difficulty judging how well they will perform on a test later. This result has been found in other experiments as well (Smith et al., 2016).

Learning Strategies Used by Students

It seems that retrieval-based learning strategies are an effective way to improve student learning. The next question is whether students use retrieval practice to study, and if doing so is linked to academic achievement. Hartwig and Dunlosky (2012) conducted a survey that investigated the relationship between self-testing and study time scheduling, to the range of GPA. They were specifically interested in individual differences. They investigated whether successful students used effective learning strategies, and whether students with lower GPAs used learning strategies that we know to be relatively ineffective. The survey was an expanded version of a questionnaire used in a previous study by Kornell and Bjork (2007). The questionnaire included inquiries of their GPA and their learning strategies. The results demonstrated a relationship between reported self-testing and GPA. Those with lower GPAs reported using self-testing as a study strategy less than those with higher GPAs. In addition, lower performers were more likely to cram and study late at night compared to higher performers. By surveying the students, we can get a glimpse as to how often students are using effective study strategies, like recall, in real life learning.

Hypotheses

First, we asked whether retrieval-based learning strategies are effective at producing meaningful learning in undergraduate college students in the PEP program (research question 1). Based on previous literature, we hypothesized that strategies that were effective with the typical undergraduate college students will be just as effective for this special population. Thus, we

hypothesized that the retrieval-based learning strategy would lead to more meaningful learning than the control strategy.

However, we also asked whether individual learner characteristics, such as reading comprehension and speed of processing, determined how effective retrieval-based learning strategies were for students (research question 2). It is possible that reading comprehension score and speed of processing will interact with the effectiveness of retrieval-based learning strategies. On the one hand, if low reading comprehension or low speed of processing leads students to retrieve less information during the retrieval-based learning strategy, then these students may not benefit from retrieval-based learning strategies as much as students with higher scores on these dimensions because retrieval success is important (Smith et al., 2016). On the other hand, giving students with lower reading comprehension and speed of processing scores the opportunity to practice retrieval may help them learn more, thus minimizing the gap between these students and those with higher scores. For example, Karpicke and colleagues (2016) found that speed of processing and reading comprehension did not alter the effects of retrieval practice for fourth grade students, and Agarwal, Finley, Rose, and Roediger (2017) found that retrieval practice actually helped students who had lower working memory scores more than those with higher working memory scores.

We were also interested in whether students in PEP were able to determine the effectiveness of their own learning after using various leaning study strategies (research question 3). Other studies have looked into the metacognition of students (their belief about their own cognition and learning). They often find that students are not aware of their own learning and what strategies are effective (Blunt & Karpicke, 2014); therefore, we hypothesized that the same would occur with this sample of students. Even if retrieval practice leads to improved

meaningful learning, we hypothesized that students would predict that rereading produced more learning than did retrieval practice. Finally, we were interested in what study strategies students in PEP are using already (research question 4). This is an exploratory question, and we will compare our students' responses to those from previous surveys of college students (Hartwig & Dunlosky, 2012).

Method

Participants

We recruited 28 participants from PEP at Rhode Island College. There was not a lot of diversity in terms of gender; only 5 out 28 participants were males. The participant ranged between the ages of 18 to 22, with a median age of 19. Out of the 28 participants assessed, 15 were native English speakers.

Materials

Learning Materials. We provided students with two educational texts from Cook and Mayer (1988): Tropisms and Homeostasis. Both texts contained 262 words and had Flesch-Kincaid reading levels of 8.3 and 10.4 respectively. A sample of the text is provided in Appendix A.

Learning Assessment. We assessed both metacognitive awareness of how well the students thought they learned, and their actual learning. Students were asked to provide metacognitive judgments about how well they thought they learned the material, how much they enjoyed the learning activity, how difficult they found the learning activity, and how interesting they found the learning activity (see Smith, et al., 2016).

To assess student's learning, we asked a number of short-answer questions. These include verbatim questions where they were asked to produce information they saw word-for-word in the

text, and higher-order questions where the students were asked to answer questions that went beyond what was initially presented in the text (see Smith et al., 2016). Sample verbatim and higher order questions are shown in Appendix A.

Survey regarding current study strategies. Students completed a survey about their current study habits. Questions were selected from Karpicke, Butler, and Roediger (2009) and Hartwig and Dunlosky (2012). This survey is included in Appendix B. These surveys do not have reported reliability but have been used in previous papers (Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Kornell & Bjork, 2007).

Learner Characteristics. Level of reading comprehension was assessed by using the Maze Test (Fuchs & Fuchs, 1992). To assess the students' processing speed, we used the Cross-Out task from the Woodcock-Johnson Tests of Cognitive Ability (1989; see also Kail & Hall, 1994). Samples of these tests are shown in Appendix C. We also asked for demographic information shown in Appendix D.

Design

A within-subjects design with two conditions (recall and a read-only control) was used. In the recall condition, the students were given a text to read first, and then practiced retrieval by writing as much of the information as they could remember. In the control condition, the students simply read the text. Two versions of the experiment were created in order to counterbalance the conditions. Half of the students did the recall condition first, and the other half did the read-only control condition first. Students were randomly assigned to one of the two versions of the experiment. The order of the texts was held constant, and this has been done in previous research on retrieval practice (e.g., Karpicke & Blunt, 2011; Karpicke et al., 2014). Tropisms was first

and Homeostasis was second, so that each text was used for each of the two experimental conditions. The two versions of the experiment are depicted in Figure 1.

Procedure

All procedures were approved by the IRB at Rhode Island College prior to conducting the experiment. All participants provided written consent prior to participating in the experiment.

The overall procedure is depicted in Figure 1. Students were given the texts to read and then participated in learning activities. In one learning activity they recalled as much information as possible by writing and in the other, they read the text and were allowed to make marks on the text if they wanted to. After the learning activity, we then assessed the students' metacognitive judgments of the learning strategies. Next, we tested students' level of reading comprehension and processing speed using the Maze test and the Cross-out task and the students were timed. For the Maze task, the students had 2.5 minutes to complete the task, whereas in the Cross-Out task they had 3 minutes. Students then completed a short-answer test to measure learning. Students then repeated the procedure for the second text. Finally, students answered the survey questions about their current learning strategies and completed the demographic form. Once the session was done, students were debriefed, and any questions asked by the students were answered.

Scoring

For the free recall data, we scored what the participants recalled using idea unit scoring (see Karpicke & Blunt, 2011 and Smith et al., 2016 for an example of this type of scoring). The text was broken down into idea units, each representing one simple idea from the text. The way in which our texts are broken into idea units is shown in Appendix E. Those who scored the data went through and determined, for each participant, whether they recalled each of the idea units. For each participant, we then calculated the proportion of idea units they recalled out of the total

number of idea units in the text. For the short-answer data, participants were given 1 point for correct answers, 0.5 points for partially correct answers, and 0 points for incorrect answers (see Karpicke & Blunt, 2011; Smith et al., 2016). All free recall and short-answer data were scored by two independent raters. The raters agreed on 90.1% of the items for the free recall data, and 83.9% of the items for the short-answer data. The scores were averaged in cases of disagreement.

For the Maze test, each participant received 1 point for each correctly circled answer. Blank items were counted as errors, and scoring was discontinued if three consecutive errors were made (see Fuchs & Fuchs, 1992; Karpicke et al., 2016). For the Cross-out task, participants were given 1 point for each correctly completed row. Participants were given 1 point if all five objects that were supposed to be marked were in fact marked, and none of the other objects were marked (see Kail & Hall, 1994; Karpicke et al., 2016).

For the study strategy data, all responses were coded into the computer. For open-ended responses, we identified commonly reported strategies and coded them under categories. Previous literature was used to determine the categories (Hartwig & Dunlosky, 2012).

Results

We first compared the two versions of the experiment to make sure that there were not effects of order. For the initial free recall data, there were no significant differences between the two counterbalancing versions, $t(26) = 0.98$, $p = .34$, $d = .19$. This indicates that students recalled about the same amount of material from both texts. There were also no differences between the two counterbalancing versions for the final short-answer assessment in the recall condition, $t(26) = 0.73$, $p = .48$, $d = .14$, and the control condition, $t(26) = -1.09$, $p = .29$, $d = -.21$. This indicates condition order did not affect performance. We thus continued with our analysis plan without counterbalancing order as a factor in the analyses.

Initial Free Recall Performance

On average, students recalled very little during the free recall learning task (M = .08, sd = .06). This is very low compared to what has been found in the past with college students. In other studies, college students typically recall around half of the material (Smith et al., 2016) and in some cases can recall more (Roediger & Karpicke, 2006b).

Final Short-Answer Assessment

For the first research question, we asked whether retrieval-based learning strategies were effective at producing meaningful learning in undergraduate college students in the PEP program. To answer this question, we analyzed the short-answer data from the recall and control conditions. Descriptive data from the short-answer assessment are shown in Table 1. We first analyzed the overall performance on all short-answer questions (collapsed across question type) for the two conditions using a paired t-test. The analysis indicated there was no statistical difference between the recall and control conditions, $t(27) = 0.89$, $p = .38$, $d = .17$. We also analyzed the short-answer data separated by question type. We then looked at performance on the verbatim and higher order questions separately. There was no statistical difference between the recall and control conditions for the verbatim short-answer questions, $t(27) = 0.71$, $p = .48$, $d = .13$, or for the higher order short-answer questions, $t(27) = 0.62$, $p = .54$, $d = .12$. Even though performance was numerically higher for the recall group compared to the control for both types of questions, there were no statistically significant differences.

Individual Difference Measures

For the second research question, we asked whether individual learner characteristics, such as reading comprehension and speed of processing, determined how effective retrieval-based learning strategies were for students. A correlation matrix between initial free recall, short-

answer performance across both learning conditions, reading comprehension and speed of processing are shown in Table 2. Initial recall performance was positively correlated with short-answer performance in the recall and control conditions. Short-answer performance in the recall condition was positively correlated with short-answer performance in the control condition. These correlations all make sense given that the experiment was conducted within-subjects. Reading comprehension score was also positively correlated with short-answer performance in the control condition. This means that students who have higher reading comprehension scores perform better when they have to read the text and then answer questions from memory compared to those with lower reading comprehension scores.

We ran analyses similar to those from Karpicke and colleagues (2016). We first ran a repeated measures ANCOVA with condition as the independent variable and reading comprehension as the covariate. Reading comprehension was entered as a continuous variable, and Figure 2 illustrates the results using quartiles (see Karpicke et al., 2016). When looking at all of the short-answer data together, there was a marginal main effect of condition, F (1, 26) = 3.92, p = .059, η_p^2 = .13. There was also a marginal interaction between condition and reading comprehension score, F (1, 26) = 3.08, p = .091, η_p^2 = .11. When looking only at the verbatim questions, there was no main effect of condition, F (1, 26) = 1.49, p = .23, η_p^2 = .05, and no interaction, F (1, 26) = 1.04, p = .32, η_p^2 = .04. When looking only at the higher order questions, there was a marginal main effect of condition, F (1, 26) = 3.09, p = .091, η_p^2 = .11, but no interaction, F (1, 26) = 2.68, p = .11, η_p^2 = .09. Looking at the data, performance was generally better for those with higher reading comprehension scores compared to those with lower reading comprehension scores. For students lower in reading comprehension, recall seemed to slightly

improve final performance compared to the control. This was not the case for those who had higher reading comprehension scores.

We ran the same ANCOVA but with speed of processing as the covariate. Figure 3 illustrates the results using quartiles. When looking at all of the short-answer data together, there was no main effect of condition ($F < 1$), and no interaction ($F < 1$). When looking only at the verbatim questions, there was no main effect of condition ($F < 1$), and no interaction ($F < 1$). When looking only at the higher order questions, there was no main effect of condition ($F < 1$), and no interaction ($F < 1$).

Metacognitive Ratings

For the third research question, we asked whether students in PEP are able to determine the effectiveness of their own learning after using various learning study strategies. After engaging in each learning activity, we assessed their metacognitive judgments and ratings of the tasks by asking them to rate from 0 to 100, how well they thought they would remember the information, the difficulty of the task, how much they enjoyed the task, and how interesting they found the task. The overall means and standard deviations are shown in Table 3. When comparing between the recall and study conditions, the participants on average thought they would remember more in the control condition than the recall condition (*M*s = 47 and 37 respectively). However, this difference was not significant, F (1, 27) = 2.51, p = .12, η_p^2 = .09. The participants found free recall to be more difficult than the control (*M*s = 53 and 36, respectively, F (1, 27) = 4.43, p = .045, η_p^2 = .14). They rated enjoyment higher in the study than the recall condition (*M*s = 52 and 42, respectively), however this difference was not significant, F (1, 27) = 2.67, p = .11, η_p^2 = .09. Lastly, they found the study condition more interesting than the recall condition (*M*s = 64 and 52, respectively), but again the difference was not significant F

(1, 27) = 2.03, p = .17, η_p^2 = .07. Given that there was not an overall high level of performance on the final assessment, and that there were not large differences between the two conditions, it is not surprising that the ratings are low and are not very different based on condition. Others have found that students find free recall to be more difficult than reading (Smith et al., 2016).

Self-Reported Study Strategies

We surveyed PEP students use of various study strategies. Results from our sample and that of Karpicke et al. (2009) are shown in Table 4, and results from our sample and that of Hartwig and Dunlsoky (2012) are shown in Table 5. Overall, PEP students reported using similar study strategies as the college students in Hartwig and Dunlosky (2012) and Karpicke et al., (2009). When asked to imagine reading a chapter from a textbook, more PEP students reported using recall (42.8%) than the students in the Karpicke et al., (2009) study (17.8%). This may be due to demand characteristics, where students report the use of a strategy more often because they just used the strategy in the experiment and not because they actually use the strategy on their own. The final question on our survey asked students to indicate what study strategies they currently use, and they were able to mark as many strategies as applied to them. For self-testing, 50% of PEP students reported that they currently use this strategy, which is similar to the proportion of students reporting they would use recall while studying a chapter. However, many students still report that they engage in rereading (60.7% of PEP students compared to 60% in Hartwig & Dunlosky, 2012). Additionally, a low percentage of students reported using other common strategies such as using flashcards (32.1%), making outlines (21.4%), using pictures (10.7%) and studying with friends (25%). These are strategies that could effectively help them learn and retain the information, according to the cognitive literature. The most popular study

strategy students reported using was the rereading of notes, with 60.7% of the participants reporting having done so.

Discussion

For research question 1, we examined performance on the short-answer assessment to see whether retrieval-based learning strategies were effective at producing meaningful learning in undergraduate college students in the PEP program. We hypothesized that the retrieval-based learning condition will lead to more meaningful learning than the control condition. Though the results from the recall condition were numerically higher than that of the control condition, there were no statistical differences between the two conditions. Thus our hypothesis was not supported. In comparison to other studies, there usually is a main effect of strategy, with the use of recall resulting in better performance in the final assessment (Smith et al., 2016). Additionally, we analyzed for performance between question type across the conditions and the pattern of results was the same for both types of questions. Though the results indicate that retrieval-based strategies did not yield any meaningful learning, this does not mean that it cannot be effective. Considering the demographic of our population, the strategies would have to be taught to them in order for them to be successfully utilized. In addition, prior to assessing the participants' overall performance in the final short-answer questions, we looked into initial recall performance – and students recalled very little of the material. On average, college students recall at least half of the material (Smith et al., 2016). The fact that the PEP students only recalled about 8% of the material during recall is problematic, and may explain the reason for low final assessment performance.

For research question 2, we looked into whether individual learner characteristics, such as reading comprehension and speed of processing interacted with the effectiveness of retrieval-

based learning strategies for students. The results showed that those with higher reading comprehension scores in general performed better on the final short-answer assessment. However, those with lower reading comprehension skills did perform a little bit better, numerically, in the recall condition compared to the control condition. Additionally, there was no influence on performance by question type. We also assessed the role of speed of processing on performance and there was no main effects or interactions between any of the variables. The results were the exact opposite of what we originally hypothesized. We assumed that students with low reading comprehension and speed-of-processing would not benefit as much from retrieval practice. Based on these results, it seems that all students generally had a hard time engaging in the recall task, but potentially those with lower reading comprehension scores might benefit more from retrieval practice if we can find ways to improve initial recall.

For research question 3, we investigated whether students in PEP were able to determine the effectiveness of their own learning after using various learning study strategies. We hypothesized that students would predict more learning after reading compared to retrieval practice. Numerically, students did judge learning to be higher for the reading control compared to the recall condition. However, given that recall did not improve learning on the final assessment, this is not that surprising. When rating other aspects of each task for enjoyment, interest, and difficulty, the participants favored the study condition, however, this finding was only statistically significant for the question about difficulty. This finding correlates with students' use of re-reading strategies. The fact that they do not favor the recall condition and find it to be difficult, is most likely the reason why they choose strategies other than recall when studying.

For the fourth research question, we assessed students' current study strategies. Though students reported the same strategies as those in Hartwig and Dunlosky (2012), they use retrieval practice less in comparison. But when comparing the data to that of Karpicke et al., (2009), we have an adverse result., where students of our present study report utilizing recall more than the aforementioned study. This could be because of differences in the way the question is worded. For both questions, around 50% of the PEP students reported using retrieval practice. Regardless of the differences in surveys, the students in the present study are still more likely to use re-reading as a study strategy, which is not as effective as retrieval practice according to the cognitive literature. However, most college students believe that they will greatly benefit from repeated reading (Smith et al., 2016). At the same time, the students in this study did not experience a benefit of retrieval-based learning activities compared to the reading control, so perhaps this explains why the students report utilizing rereading more. The results of the assessments in this study show that retrieval-based study strategies are not the most effective way for this population to learn and retain material. Though in other studies, retrieval-based study strategies have been shown to lead to better testing performance. Other research has also shown that with specific populations the methodology has to be modified in order for students to benefit from them (see Karpicke et al., 2014). The conclusion is not that students cannot benefit from these strategies, but they most likely have to learn how to best utilize these strategies to see improvements over time.

Limitations

While the results from this study are similar to that of Karpicke and colleagues (2014) with elementary students who had trouble practicing free recall, the results might also be attributed to the number of participants in this study. With just 28 participants, we may not have

been able to see potential significant differences that exist between the conditions. This is especially true with regard to the individual differences because these variables are inherently between subjects. With more students, the relationship between reading comprehension and speed of processing and learning strategy may become clearer. Another factor from our study that may differentiate it from other retrieval experiments is also in the population that was assessed. The majority of the participants in this study were students whose native language is not English, and this could potentially play a role in their performance. Though the learning material we used were high school textbook excerpts, students in our sample anecdotally reported that the material being learned was a bit difficult for them. At the end of the experiment, students informally reported that when having to recall the information they found it difficult to do.

Future Research

In looking into the effectiveness of retrieval-based strategies in populations alike to this one, it would be ideal to assess increases in performance over time. As mentioned before, though performance was low, it should not be interpreted as the strategy not being beneficial, but rather that it may need to be modified in order for it to produce better learning. Therefore, in future studies, initial performance can be recorded while giving students support to help them retrieve, and as students learn and utilize these strategies we can continuously assess their performance over time. Additionally, in regard to the potential language barriers, the research can be done in the participant's native language.

Another issue to address is test anxiety and attention to the task. We tried to diminish testing anxiety by letting the participants know that the results of this assessment in no way was a reflection of them as a student. However, we still tried to reinforce their attention to this study

by instructing them to take it seriously. As the person who conducted this study, I was able to see that some did not try as much as could have. Therefore, a suggestion is finding a mediation between having students not be anxious while doing this study but also taking it seriously and giving the necessary focus.

Implications

There is a copious amount of literature on study strategies that best benefits students, and the results of this study contribute to the differences that exist when analyzing their effectiveness. First generation college students, like those in this study, in general, do have a more difficult time succeeding at a collegiate level (Stephens et al., 2012). The findings of this study indicate that study strategies that researchers might recommend for some college students may not work well with all students. With the results of this study, we can help programs like PEP formulate ways to best advise these students. This research also can change the way people choose to tutor their students. Personally, with my knowledge of these results, my approach in teaching information to other students will be more tailored and will involve more scaffolding.

Though in this present study we were not able to see the evidence of the benefits of recall as a study strategy, it still extends our knowledge of study strategies and how they apply across the board. It is important to note that retrieval-based study strategies such as active recalling still may be beneficial when it comes to learning and retaining information, but if students are unable to recall a lot during retrieval then engaging in free recall may not produce large learning benefits.

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Table 1

Mean performance on final short-answer assessment by question type and condition

	Recall Condition	Control Condition
Verbatim Questions	.26 (.21)	.22 (.25)
Higher Order Questions	.21 (.23)	.19 (.16)
All Short-Answer Questions	.24 (.19)	.21 (.18)

Note. Standard deviations are reported in parentheses.

Table 2

Correlation matrix between initial free recall, short-answer (SA) performance for both learning conditions, reading comprehension scores and speed of processing scores

	1	2	3	4	5
Initial Free Recall	1				
Final SA Recall	.60*	1			
Final SA Control	.50*	.60*	1		
Reading Comprehension	.30	.19	.50*	1	
Speed of Processing	.32	.36	.29	.26	1

Note. * indicates significance at the .05 level

Table 3

Mean metacognitive ratings of the learning tasks made on a scale from 0 to 100

	Recall Condition	Control Condition
Remembering	37.25 (26.67)	46.68 (24.80)
Difficulty	52.68 (29.39)	35.96 (33.45)
Enjoyment	42.68 (28.63)	51.79 (24.20)
Interest	53.75 (32.36)	64.12 (27.56)

Note. Standard deviations are reported in parentheses.

Table 4

Reported study strategy use compared to Karpicke et al., (2009)

Item	Response	Karpicke Study	Present Data
Imagine you are reading a textbook chapter for an upcoming exam. After you read the chapter one time would you rather:	A. Go back and restudy	57.4%	42.8%
	B. Try to recall	17.8%	42.8%
	C. Use some other study technique	20.7%	14.4%

Table 5

Reported study strategy use compared to Hartwig and Dunlosky (2012)

Item	Response	Hartwig & Dunlosky Study	Present Data
Would you say you study the way you do because a teacher(s) taught you to study that way?	Yes	36%	35.7%
	No	64%	64.3%
How did you decide what to study first?	Whatever I hadn't studied for the longest time	2%	25%
	Whatever I found interesting	5%	7.1%
	Whatever I felt I understood the least	24%	53.6%
	I planned my schedule ahead of time, and I studied whatever I'd scheduled	13%	14.3%
If you quiz yourself, why do you do so when you study?	I learn more that way than I would through rereading	27%	25%
	To figure out how well I have learned the information I'm studying	54%	39.3%
	I find quizzing more enjoyable than reading	10%	3.7%
	I usually do not quiz myself	9%	7.1%
	No response		25%
While you were studying, you probably felt confident that you knew the answer to a certain question. When this happened, what did you do?	Studied it (or tested yourself on it) again later	46%	64.3%
	Put it aside and focus on other material	54%	28.6%
	No response		7.1%

Which of the following best describes your pattern of study?	I spaced out my study sessions over multiple days or weeks	47%	57.1%
	I did my studying in one session before the test	53%	42.8%
Study Strategies Used (multiple selections permitted)	Tested yourself with questions or practice problems	71%	50%
	Used flashcards	62%	32.1%
	Recopied your notes	33%	35.7%
	Reread chapters, slides, articles, notes, etc.	66%	60.7%
	Made outlines	22%	21.4%
	Underlined or highlighted while reading	72%	64.2%
	Made diagrams, charts, or pictures	15%	10.7%
	Studied with friends	50%	25%
	“Crammed” lots of information the night before the test	66%	35.1%
	Asked questions or verbally participated in class	37%	28.6%

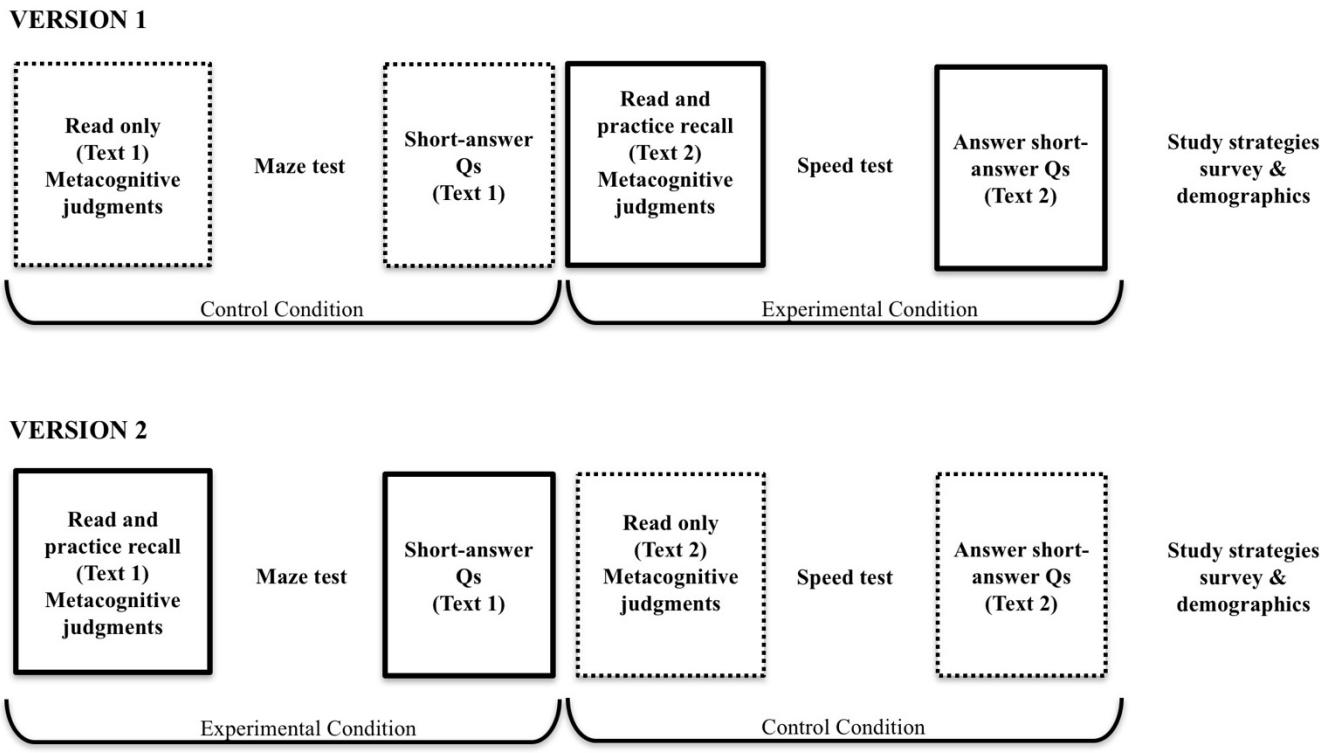


Figure 1. Visual depiction of the experimental procedure. To counterbalance the order of conditions, there will be two versions of the experiment.

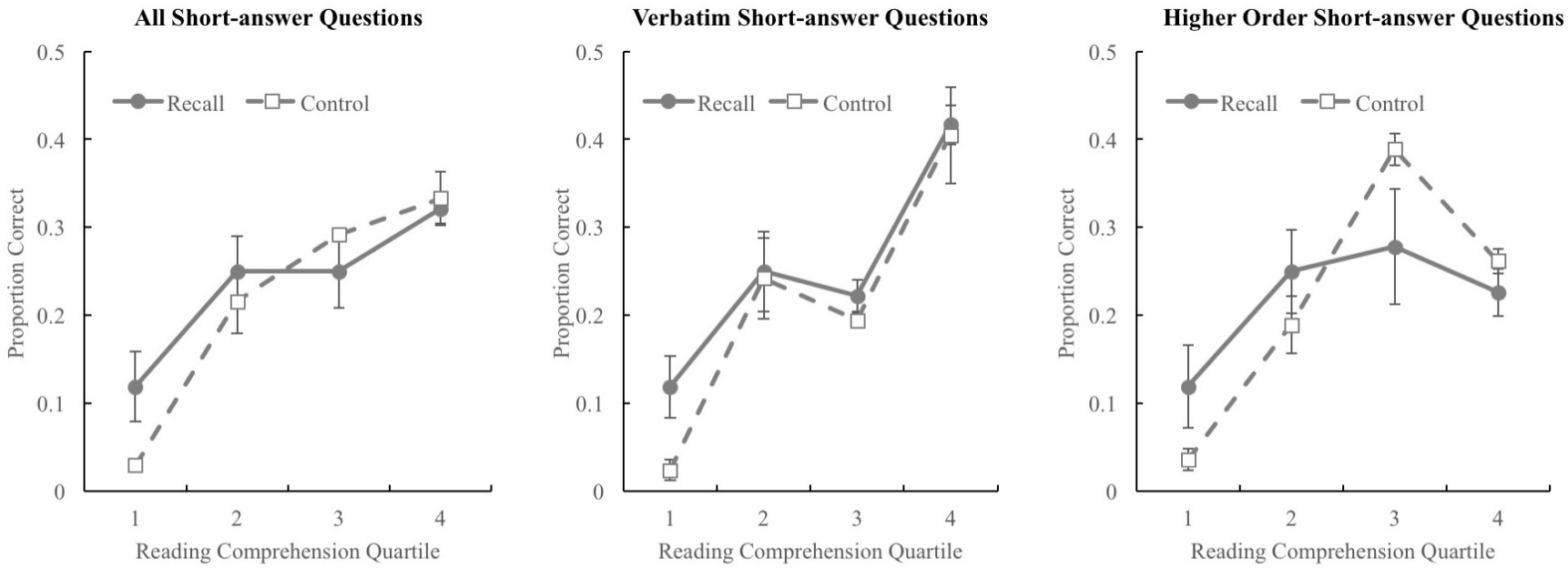


Figure 2. Performance on final short-answer assessment by condition based on reading comprehension scores. Quartiles were created using an online interquartile calculator from Statistics How To (2018). The interquartile range for the reading comprehension data was 6.0.

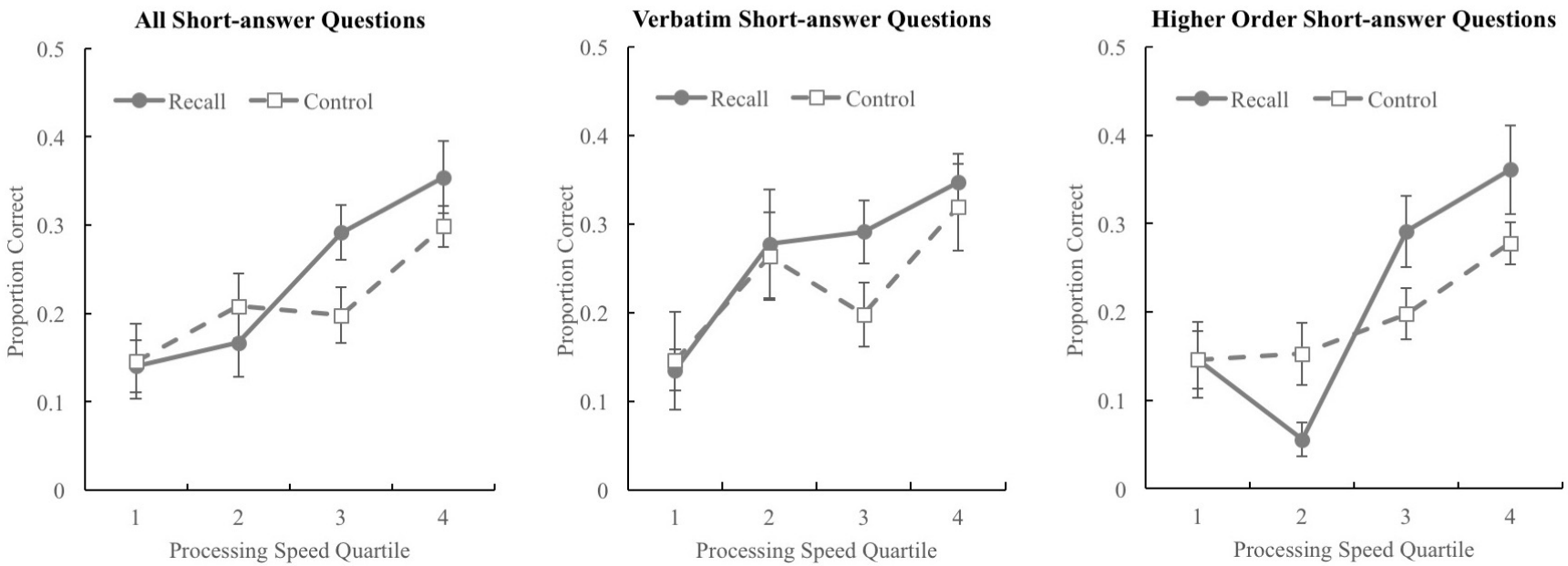


Figure 3. Performance on final short-answer assessment by condition based on processing speed scores. Quartiles were created using an online interquartile calculator from Statistics How To (2018). The interquartile range for the processing speed data was 8.0.

Appendix A

Texts and Questions

Tropisms

Growing plants can respond to a stimulus coming from a given direction by growing more rapidly on one side than the other and hence bending toward or away from the stimulus. This growth response in plants is defined as tropism. Tropisms can occur only in those parts of the plant that are growing and elongating, such as the plant stem or root. For example, a plant leaf on the window sill will gradually grow so that the stems bend toward the light source. The bending of the stems occurs because the cells on the nonlighted side grow more rapidly than those facing the light. The particular chemical responsible for this growth is called an auxin. Tropisms are named for the kind of stimuli eliciting them. A phototropism is a growth response to light. The plant on the window sill described above is a good example of a phototropic response. Geotropism is a growth response to gravity. The root of the plant is geotropic because it grows toward the force of gravity. Two other forms of tropism are chemotropism (a growth response to some chemical) and thigmotropism (a growth response to contact). Bean plants are famous for their thigmotropism. Once contact is made with the top of a bean stem, it curls, producing the clinging response typically found in these plants.

A tropic growth may be either positive (toward the stimulus) or negative (away from the stimulus). For example, a seed always grows with the root downward and the stem upward. Thus, the root is positively geotropic, and the stem is negatively geotropic.

Questions

V denotes Verbatim Question; HO denotes Higher Order Question

1. (V) What is tropism?
2. (V) Where can tropisms occur?
3. (V) What is the name of a growth response to light?
4. (V) What is geotropism?
5. (V) What is chemotropism?
6. (V) What plants are famous for their thigmotropism?
7. (HO) Imagine a plant has too much exposure to the sun, what kind of tropism will it engage in? (Please include positive/negative and the type of tropism)
8. (HO) The right side of a plant is exposed to more sunlight than the left side. In order to expose light to the entire plant, the leaves of which side of the plant will grow?
9. (HO) If all the leaves of a bean plant are not curled, what can be assumed regarding tropism?

10. (HO) How does auxin cause plants to grow towards light?
11. (HO) Compare and contrast chemotropism and thigmotropism.
12. (HO) A negative geotropic growth means that the stem is growing in which direction?

Homeostasis

The human body has an amazing capacity to speed up or slow down physiological processes when changes occur in internal states. This ability is defined as homeostasis. The most sophisticated system in our body which carries out homeostasis is the endocrine system. This is a series of glands in our body which produce hormones. The endocrine system operates on a principle similar to a home heating unit. A thermostat detects the need for heat, turns on the furnace when the temperature is too low, and then turns off the furnace when the temperature is again normal.

One example is the hormone vasopressin, which causes the capillaries to constrict. When the body suffers severe bleeding due to an injury, the amount of this hormone is drastically increased. This helps to slow down blood flow by closing off small blood vessels. Thus, blood flow to the injured area is reduced. The antidiuretic hormone, ADH, helps the body conserve water by directing the kidneys to reabsorb water. A normal amount of ADH tells the kidneys to reabsorb all but one liter of water daily. However, when the body becomes dehydrated from water loss due to perspiration during hot weather, more ADH is released telling the kidneys to reabsorb more water than usual to make up for that loss.

Sometimes the production of a hormone in the body may be either overactive or underactive, regardless of internal needs. If it is overactive, it is called “hyper-” and if it is underactive “hypo-”. For example, hyperthyroid conditions produce too much growth while hypothyroid conditions produce stunted growth.

Questions

V denotes Verbatim Question; HO denotes Higher Order Question

1. (V) What is homeostasis?
2. (V) When is the level of vasopressin increased?
3. (V) How much water does a normal amount of ADH tell the body to reabsorb per day?
4. (V) What does the body do when it is dehydrated?
5. (V) What prefix is given if a hormone in the body is overactive?
6. (V) What occurs as a result of hypothyroid conditions?
7. (HO) If the glands of the endocrine system stopped working, homeostasis would no longer be possible. Why?

8. (HO) Ghrelin is a hormone that makes us hungry. If a person has hyperactive Ghrelin production, what can we conclude about the amount of hormone released?
9. (HO) The number of restroom breaks during a summer game of kickball might tend to be inversely related to the temperature outside. Why would this be a legitimate theory?
10. (HO) How is the release of vasopressin and ADH similar?
11. (HO) If a child's thyroid hormone production were underactive, what would happen to his/her growth?
12. (HO) Which hormone closes off small blood vessels?

Appendix B

Study Strategies Survey

Please answer the following questions honestly. Your responses will not be associated with your exam and will not be considered when grading your exam.

1. What kind of strategies did you use when studying for this exam? List as many strategies as you used.

2. From the list above, circle the strategy that you used the most.

3. Assuming that you read the textbook for this test, after you read each chapter one time, did you **(circle one):**
    a. Go back and restudy either the entire chapter or certain parts of the chapter.
    b. Try to recall material from the chapter
    c. Use some other technique.

4. Would you say that you studied for this exam the way you did because a teacher (or teachers) taught you to study that way **(circle one)**?
    a. Yes
    b. No

5. How did you decide what to study first **(circle one)**?
    a. Whatever I hadn't studied for the longest time
    b. Whatever I found interesting
    c. Whatever I felt I understood the least
    d. I planned my study schedule ahead of time, and I studied whatever I'd scheduled

6. During this section of the course, did you return to class material to review it after each class ended **(circle one)**?
    a. Yes
    b. No

7. When you studied for this exam, did you read course materials (the textbook chapter, slides, articles, other resources) more than once **(circle one)**?
    a. Yes, I reread whole chapters, slides, or articles
    b. Yes, I reread sections that I underlined, highlighted, or marked
    c. Not usually

8. If quizzes were not required in this class, would you have quizzed yourself while you studied for this exam (either using a quiz at the end of the chapter, or a practice quiz, or flashcards, or something else) **(circle one)**?
    a. Yes
    b. No

9. If you answered yes to #8, why would you do so **(circle one)**?
    a. I learn more that way than I would through rereading
    b. To figure out how well I have learned the information I'm studying
    c. I find quizzing more enjoyable than reading
    d. I usually do not quiz myself

10. While you were studying, you probably felt confident that you knew the answer to a certain question (e.g., the definition of a term in psychology). When this happened, what did you do **(circle one)**?
    a. Studied it (or tested yourself on it) again later
    b. Put it aside and focused on other material

11. Which of the following best describes your pattern of study for the current exam **(circle one)**?
    a. I spaced out my study sessions over multiple days or weeks
    b. I did my studying in one session before the test

For the last question, circle as many as you want!

12. Which of the following study strategies did you use to study for this exam? **(circle all that apply to you)**
    a. Tested yourself with questions or practice problems
    b. Used flashcards
    c. Recopied your notes
    d. Re-read chapters, slides, articles, notes, etc.
    e. Made outlines
    f. Underlined or highlighted while reading
    g. Made diagrams, charts, or pictures
    h. Studied with friends
    i. "Crammed" lots of information the night before the test
    j. Asked questions or verbally participated in class
    k. Other (please describe):_____

Appendix C

Sample Maze Test

Practice Sentence:

The snow was falling and the air was crisp. He put on his **trees / boots / houses** and walked to school.

Predicting Weather:

At one time or another, everyone has stopped to think about the weather. Some days the weather is good. **(Lose / Some / Wife)** days the weather is bad. Still, **(there / smart /focus)** are days when the weather seems **(hit / is / to)** change from hour to hour. A **(day / raw / jog)** that starts out fine might not **(cave / yard / keep)** its promise. Sometimes a day that **(worst / seems / brain)** bad turns out better than you **(desolate / because / thought)** it would.

There are ways of **(everywhere / salespeople / understanding)** the weather. One way is to **(mirror / study / above)** the clouds. No two clouds are **(lose / tomb / ever)** alike. But it is still possible **(to / pet / mix)** group clouds and to give them **(names / adjust / empty)**. You can learn to recognize the **(chopstick / different / stewardess)** kinds of clouds and watch them **(glass / move / tomb)** across the sky.

As a rule, **(the / hit / few)** higher the clouds, the better the **(forgets / through / weather),** and the lower the clouds, the **(grade / worse / finish)** the weather is likely to be. **(To / Hi / Is)** predict the weather, you should look **(for / wow / tip)** three things about clouds: movement, color, **(pet / and / wet)** change. Clouds can tell you if **(I / go / a)** storm is on the way. For **(satisfy / example / survive)**, cirrus clouds are high, thin, and **(mine / tent / airy)** clouds. They can become thick and **(move / site / brow)** lower. This means rain is on **(set / the / mix)** way. Cumulus clouds are puffy clouds **(stay / beef / that)** look like balls of cotton. If **(they / huge /**

sell) get bigger early in the day, **(then / tent / brow)** you know it will rain. If **(there / brave / elect)** is a sudden, cool breeze and **(is / a / I)** dark thundercloud appears, then a storm **(he / to / is)** about to break out.

Clouds are **(hat / not / vet)** only signs of storms and rain. **(They / Surf / Envy)** may also be signs of good **(strange / weather / bottom)**. The cirrus clouds may stay high **(in / be / go)** the sky and move very slowly. **(Lose / Still / This)** means fine weather. Fair weather cumulus **(matter / active / clouds)** are another sign of good weather.

(Colors / Smart / While) in the sky tell us about **(see / the / win)** weather, too. A golden ring around **(the / hit / add)** moon tells us that a storm **(he / is / by)** on the way. A watery, yellow **(simple / remote / sunset)** is a sign that rain may **(to / be / my)** near.

A rainbow has a message, **(too / see / wet)**. The colors of the rainbow come **(from /move / goes)** sun rays shining through falling rain. **(By / He / If)** you see the sun in the **(walk / east / thin)** and a rainbow in the west, **(fill / the / cup)** rain may be coming your way. **(If / Go / In)** the sun is in the west **(mad / ton / and)** the rainbow is in the east, **(cow / soy / the)** rain will be moving away from **(you / buy / how).**

Clouds are a sign of changing **(weather / similar / manage).** So are the colors in the **(sky / wet / sit).** Knowing a little about them both can help you become weather wise.

Stories that point out lessons are called fables. Nearly everyone knows the fable about **(the / wet / rob)** three little pigs. They leave home **(to / go / is)** make their fortunes. They build places **(he / in / go)** which to live. The first little **(sat / for / pig)** makes his house of straw. The **(second / knock / borrow)** little pig builds his house of **(among/ sticks / retire)**. The third little pig works hard **(to / he / no)** make a house of bricks. It **(my / is / on)** a good, sturdy house. A wolf **(loyal / whole / comes)** over and blows down the houses **(be / of /go)** straw and sticks. It eats up

(the / jog / tip) little pigs. But all its huffing **(mad / hit / and)** puffing cannot blow down the house **(of / go / hi)** bricks. The third pig stays safe.

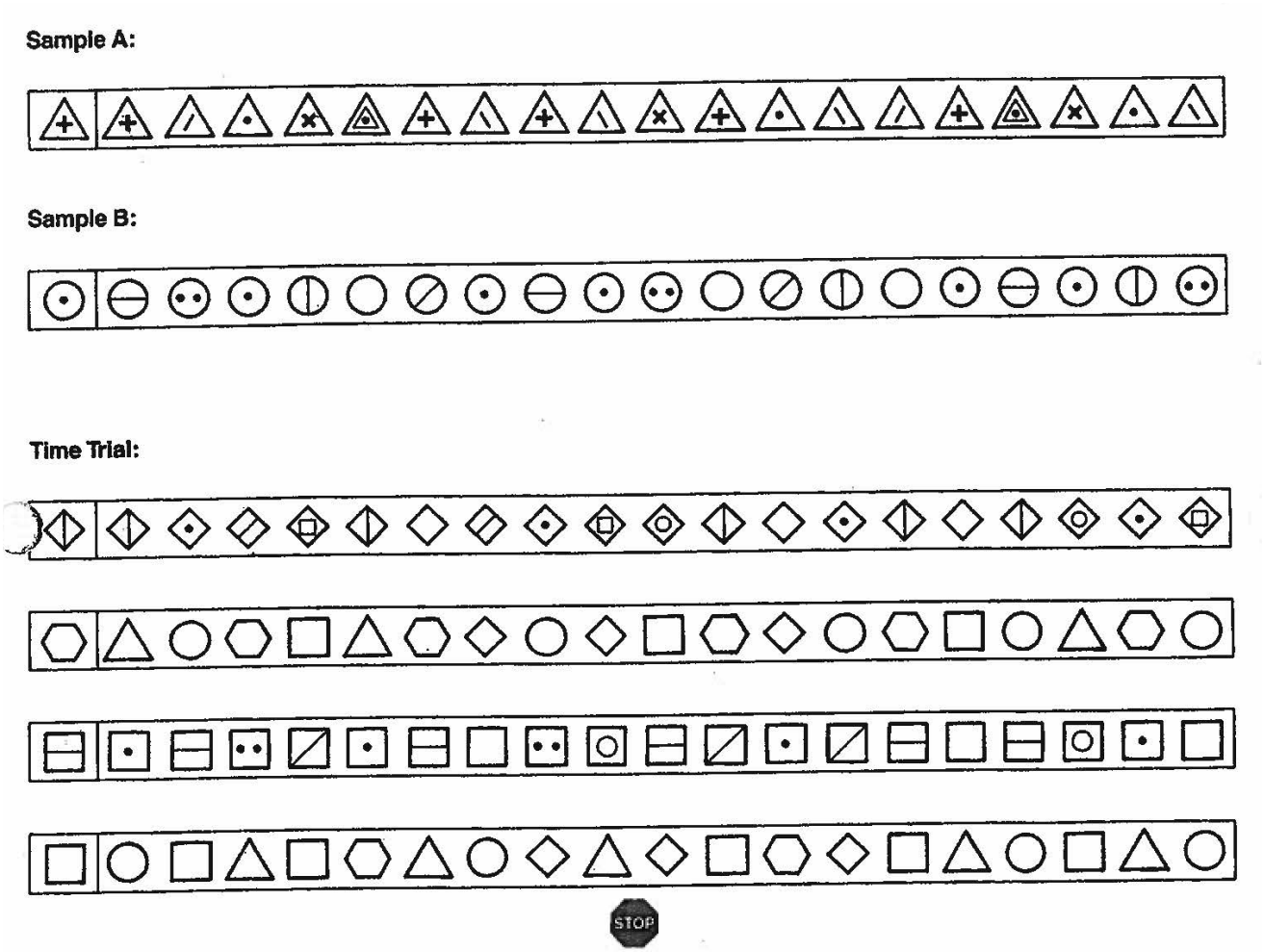
(Say / The / Lie) story of the little pigs teaches **(lost / wipe / that)** those who work hard are rewarded. **(By / It / Go)** is just one fable that uses **(animals / strange / reflect)** to teach a human lessons. Many **(invite / claim / other)** fables also use animals to teach **(continue/ lessons/ believe)**. The greatest fable teller, Aesop, told**(stories/ hidden/ adjust)** that usually featured animals.

In Aesop's "**(The / Sea / Mix)** Lion and the Mouse," the story **(by / is / us)** about a powerful lion and a **(see / has / tiny)** mouse. One day, the lion tires **(my / hi / of)** hunting and falls asleep under a **(wear / tree / drop)**. Soon a small mouse runs over **(lie / fan / his)** face and awakens him. As the **(angry / stove / elect)** lion is about to crush the **(went / tiny / quit)** mouse, the mouse begs to live. **(Go / My / So)** the lion lets the mouse go. **(Some / Lift / Chip)** time later, the lion is caught **(in / go / top)** a hunter's trap. The lion roars **(sale / with / envy)** surprise and fury. The mouse hears **(sad / rug / the)** roar and races to the trap. **(To / It / My)** gnaws the ropes and sets the **(lion / work / sure)** free. The powerful lion thanks the **(sweet / mouse / divide)** and thinks to itself, "Sometimes the **(weakest / distance / produce)** can help the strongest."

Aesop's "The **(Fox / Ago / Sew)** and the Stork" shows that a**(tricky / weigh / appear)** person does not always win. A **(big / age / fox)** invites a stork to dinner. The **(sad / fox / low)** serves soup in a shallow dish. **(Say / The / Box**) poor stork can wet only the **(end / met / let)** of its long narrow bill in **(for / add / the)** soup. The sly fox makes false **(incredible / frustrate / apologies)** and eats up all the soup. **(The / Lip / Bat)** stork pretends to be satisfied and **(invites / husband / forever)** the fox to dinner. When the **(cue / fox / dye)** comes a few days later, it **(brown / finds / curse)** the food served in a tall **(due / raw / jar)** with a narrow neck. Stork's

long **(bill / lean / seem)** goes down in the jar. The **(low / fox / may)** only can do is lick its chops. This fable may have suggested the old proverb "One who laughs last laughs best."

Sample Speed of Processing Test



Appendix D

Demographics

1. What is your sex: Female / Male / Other
2. What is your current age? _____
3. What is your race / ethnicity? Check all that apply to you
    - ☐ African American / Black
    - ☐ Asian
    - ☐ Hispanic / Latino
    - ☐ Native American
    - ☐ Pacific Islander
    - ☐ White / Caucasian
    - ☐ Other: _____
4. Are you a native speaker of English? Yes / No

    If no, what is your native Language? _____
5. Do you have any learning disabilities? Yes / No

    If yes, what is your diagnosed learning disability? (if multiple, please list all learning disabilities) _____

Appendix E

Texts Broken Down Into Idea Units

Tropisms

1. Growing plants can respond to a stimulus coming from a given direction
2. (plants respond by) growing more rapidly on one side than the other
3. (plants) bend toward or away from the stimulus
4. Growth response in plants is defined as tropism
5. Tropisms can occur only in those parts of the plant that are growing and elongating
6. (tropism can occur in the) plant stem or root.
7. A plant leaf on the window sill will gradually grow so that the stems bend toward the light source
8. The bending of the stems occurs because the cells on the nonlighted side grow more rapidly than those facing the light
9. The particular chemical responsible for this growth is called an auxin
10. Tropisms are named for the kind of stimuli eliciting them
11. A phototropism is a growth response to light
12. The plant on the windowsill is a good example of a phototropic response
13. Geotropism is a growth response to gravity
14. The root of the plant is geotropic
15. (It is geotropic because it) grows toward the force of gravity
16. Chemotropism is a form of tropism
17. (chemotropism is) a growth response to some chemical
18. Thigmotropism is a form of tropism
19. (Thigmotropism is) a growth response to contact
20. Bean plants are famous for their thigmotropism
21. Once contact is made with the top of a bean stem, it curls
22. (Contact produces) the clinging response typically found in these plants
23. A tropic growth may be positive
24. (positive means) towards the stimulus
25. A tropic growth may be negative
26. (negative means) away from the stimulus
27. A seed always grows with the root downward
28. A seed always grows with the stem upward
29. The root is positively geotropic
30. The stem is negatively geotropic

Homeostasis

1. The human body has an amazing capacity to speed up physiological processes.
2. The human body has an amazing capacity to slow down physiological processes.
3. (the body) does this when changes occur in the internal states.
4. This ability is defined as homeostasis.
5. The most sophisticated system in our body is the endocrine system.
6. (the endocrine system) carries out homeostasis.

7. (the endocrine system) is a series of glands in our body.
8. (the glands) produce hormones.
9. The endocrine system operates on a principle similar to a home heating unit.
10. thermostat detects the need for heat.
11. (a thermostat) turns on the furnace when the temperature is too low.
12. (a thermostat) turns off the furnace when the temperature is again normal.
13. Vasopressin causes the capillaries to constrict.
14. When the body suffers severe bleeding due to an injury, the amount of this hormone is drastically increased.
15. [releasing of the hormone] helps to slow down blood flow
16. [Vasopressin slows blood flow] by closing off small blood vessels.
17. Thus, blood flow to the injured area is reduced.
18. The antidiuretic hormone, ADH, helps the body conserve water.
19. (ADH does this) by directing the kidneys to reabsorb water.
20. A normal amount of ADH tells the kidneys to reabsorb all but one liter of water daily.
21. However, when the body becomes dehydrated, more ADH is released.
22. (more ADH) tells the kidneys to reabsorb more water than usual.
23. (reabsorbing more water than usual) makes up for that loss.
24. Sometimes the production of a hormone in the body may be overactive.
25. Sometimes the production of a hormone in the body may be underactive.
26. (It can be overactive/underactive) regardless of internal needs.
27. If it is overactive, it is called “hyper-”
28. If it is underactive “hypo-”
29. Hyperthyroid conditions produce too much growth.
30. Hypothyroid conditions produce stunted growth.