Disentangling the Effects of Study Time and Study Strategy on Undergraduate Test Performance

Zachary J. Cole and Darrell L. Butler*
Ball State University

ABSTRACT. Increased study time is associated with improved memory. Students tend to use study time as a benchmark for gauging how prepared they are for a test. While studying, students tend to rely on rote memorization. This has led to students using judgments of processing fluency to determine their level of understanding for the study material. Elaboration, or active learning, is also associated with improved memory. The effects of elaboration appear to be confounded with study time. Two experiments were conducted to disentangle the effects of study time and study strategy on test performance. For both experiments, participants read an article, were randomly assigned to study elaboration or memorization flashcards, and took a test. In Experiment 1, study time was not controlled. Experiment 2 followed the same procedure as Experiment 1 except participants were randomly assigned to study for 7.5 or 15 minutes. For Experiment 1, the elaboration group studied longer (they had more to study), but were actually more efficient than the memorization group. The elaboration and memorization groups scored better on the test than the control group. For Experiment 2, the extended study condition scored better than the brief study condition, and the elaboration condition scored better than the memorization condition. There was no interaction between the study time and study strategy conditions. These findings suggest that study time and study strategy act independently to affect test performance.

Keywords: study time, processing time, elaboration, memorization, test performance

S tudy time is frequently positively associated with memory performance (e.g., d’Ydewalle, Swerts, & Corte, 1983), a principle known as the total time hypothesis (first reported by Ebbinghaus, 1885). When provided with a finite amount of study material, students who study longer score better on tests (Cooper & Pantle, 1967). As a result, study time and academic success are often considered complementary (Karpicke, Butler, & Roediger, 2009; Kornell & Bjork, 2007; Landrum, Turrisi, & Brandel, 2006).

In a series of studies observing junior high, high school, and undergraduate students, Christopoulos, Rohwer, and Thomas (1987) and Dellucchi, Rohwer, and Thomas (1987) found that study time increased with grade level. This increase in study time was attributed to an increase in the workload demands of coursework at higher grade levels (Christopoulos et al., 1987). Alternatively, in a similar set of studies, Curley, Estrin, Thomas, & Rohwer (1983) and Thomas, Iventosch, and Rohwer (1987) suggested that changes in study time can be attributed to the demands and characteristics of the coursework.

In an effort to explore the effects of coursework on study time, d’Ydewalle et al. (1983) found that students who were anticipating a more difficult test studied longer, and might have used more elaborative study strategies. Additionally, the students expecting a more difficult test performed better, regardless of the actual difficulty of the test (d’Ydewalle et al., 1983). These findings, in
conjunction with the understanding that more elaborate study methods take longer to carry out (Entwistle & McCune, 2004; Hilgard, Irvine, & Whipple, 1953), have led to the belief that students who study longer must be achieving a more meaningful understanding of the studied material (i.e., d’Ydewalle et al., 1983).

A meaningful understanding for the studied material is characterized by a holistic conceptual knowledge for the newly learned material (Ausubel, 2012; Mayer, 2002), which has been integrated with previously understood concepts (Ausubel, 2012; Baddeley, 2000) and is likely well-organized (Bower, 1970). One form of meaningful learning is known as elaboration (Mayer, 2002; Novak, 2002), typically defined as thinking about the material rather than just repeating the information over and over. Similarly, some have argued that active reading is fundamental to meaningful learning. Adler and Van Doren (1972) originated and defined the concept of active learning as applying specific strategies, such as summarizing, criticizing, or developing and using study guides or other artifacts in an effort to comprehend, memorize, and synthesize information. Since then, a number of frameworks have been offered to help learners develop good active reading approaches (e.g., Artis, 2008; Carlston, 2011; Pugh, 1978; Zhang et al., 2002).

Compared to elaborate study methods, memorization results in an atomistic conceptual understanding by solidifying memory for the studied material (Ausubel, 2012; Mayer, 2002; Roediger & Karpicke, 2006). The atomistic nature of memorization results in relatively isolated memories for the studied information (Novak, 2002) that are comparatively less robust than memories created using elaboration (Craik & Lockhart, 1972).

The belief that meaningful learning methods require more study time (e.g., Entwistle & McCune, 2004; Hilgard et al., 1953) is at odds with more recent evidence suggesting that elaboration is actually more efficient than memorization (Karpicke et al., 2009; Roediger & Karpicke, 2006). Claims of elaborative efficiency are supported on two theoretical fronts: (a) The association between study time and performance can be attributed to more material being studied, but not elaborated (Christopoulos et al., 1987; Dunlosky et al., 2013); and (b) elaboration requires less repetitive maintenance than memorization (Bobrow & Bower, 1969; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger & Karpicke, 2006). The redundant nature of reading and rereading notes or other materials is inherently lacking efficiency, and can lead to longer total study times and worse performance than studying to achieve a more meaningful understanding of the material (e.g., Bower, Clark, Lesgold, & Wiznenz, 1969).

Karpicke et al. (2009) has suggested that the misplaced sense of efficacy in unproductive study strategies is supported by judgments of preparedness that are based on processing fluency, rather than actual indicators of preparedness (e.g., ability to retrieve studied information). In other words, students believe they have a strong understanding of the study material when it becomes easier to read.

There is no objective threshold that can be used to identify whether a concept is understood meaningfully (Bradshaw & Anderson, 1982). According to Karpicke et al. (2009), the lack of understanding among college students of what constitutes effective learning has led to a culture of students largely dependent on the use of study strategies that contribute to an overwhelming “illusion of competence” (p. 478).

Purpose

Contrary to the evidence described above, the prevailing zeitgeist appears to presume that increased study times lead to a more meaningful understanding of the studied material (Karpicke et al., 2009). Although increased study time is associated with better academic performance (Cooper & Pantle, 1967; Keith, 1982), this effect appears to be confounded with study strategy selection (e.g., Bower et al., 1969, Karpicke & Roediger, 2008). The goal of the experiments reported below was to disentangle the effects of study time and study strategy by demonstrating their respective influence on test performance.

Experiment 1

Participants read a research article then studied elaboration or memorization flashcards in preparation for a test. The amount of study material might not have been equivalent for elaboration and memorization groups, thus confounding study time and type of study. For example, students studying to memorize concepts and their definitions might have read fewer words than students studying materials designed to encourage elaboration. For this reason, Experiment 1 was designed to measure processing time per word (efficiency) in addition to total study time. Study time was not controlled in this experiment.
We hypothesized that: (H₁) Students would study longer when the amount of study materials was greater. Thus, participants in the elaboration group would study for a longer total period of time than the participants in the memorization group. We also expected that (H₂) elaboration would be more efficient than memorization. Thus, the elaboration group was anticipated to exhibit a shorter word processing time than the memorization group. Third, (H₃) the elaboration group was hypothesized to exhibit a deeper understanding for the material by performing better on the test than participants in the memorization and control groups.

**Method**

**Participants.** The sample consisted of 97 undergraduates attending Ball State University. The sample represented a diverse cross section of majors offered at the university. Participants were mostly White (84.5%), women (n = 67), between 18 and 50 years old (M age = 21.6, SD = 5.7). The rest of the sample consisted of 30 men. The ethnicities making up the rest of the sample were 2.1% African American, 1% Hispanic, 1% Native American, and 1% Middle Eastern. All participants were awarded class research credit in exchange for participating in the experiment.

**Materials and procedure.** This experiment was conducted entirely over the Internet. Responses to online research studies have been found to be reasonably equivalent to those conducted in a laboratory setting (Butler, 1986; Whitley & Kite, 2013). For this reason, the expediency of online data collection led us to conduct the entire experiment within an online Qualtrics survey. Participants were randomly assigned to one of three groups: memorization, elaboration, or control. Data collection continued until each group reached at least 30 participants.

The experiment consisted of four phases: (a) read, (b) study, (c) distraction, and (d) testing. The memorization and elaboration groups carried out all four phases of the experiment, but studied different flashcards during the study phase. The control group did not participate in the study phase of the experiment.

At the start of the survey, participants were presented with the informed consent. After agreeing to participate, participants were presented with a concise and detailed briefing explaining the procedure. The briefing explained that a minimum score of 75% on the test was necessary to demonstrate a sufficient level of comprehension for the studied material. Furthermore, participants were led to believe that if they were to score below the threshold of 75% on the test, they would be asked to restudy the material and take another test. Participants were not actually held to this standard. The purpose of this deception was to provide a standard performance goal for all participants, and to motivate them to take the task seriously. The performance threshold was set at 75% because this was deemed a level that most college students believe they can achieve with a reasonable effort.

After being briefed, participants began the read phase of the experiment. They were presented with an article by Mathews (2014) titled, “Hoarding Disorder: More Than Just a Problem of Too Much Stuff.” This article was chosen because there was enough detailed content to make the test difficult, but not an excessive number of technical terms that might be difficult for participants to understand. Definitions that were likely beyond a colloquial level of understanding were accompanied with a definition to improve readability. The article was 55 sentences long, totaling 1,926 words in length. The provided definitions were included in the overall wordcount. The edited article was submitted to a readability analysis using Microsoft Word’s built-in tools. The readability analysis provided the following readability statistics: Flesch Reading Ease = 14.4; Flesch-Kinkaid Grade Level = 19.7; Passive Sentences = 21.4%.

After 10 minutes, participants in the memorization and elaboration groups were automatically redirected to the study phase of the experiment. After being redirected, participants were not able to navigate back to the reading material. The study material consisted of 20 flashcards covering information taken directly from the article. All flashcards consisted of two sides. Side A posed a question, and Side B provided an answer. All flashcards studied by the memorization and elaboration groups were matched for content. For the memorization group, the answer on Side B of the flashcard consisted of factual or definitive information described in the article (see Figure 1). For the elaboration group, the answer on Side B of the flashcard consisted of the same factual information provided to the memorization group, and an additional applied example (see Figure 2).

The flashcards were presented one side at a time in chronological order to match the presentation of associated concepts in the reading material. Participants were only able to navigate forward
through the flashcards. They read and proceeded through the flashcards at a self-determined pace. The flashcards presented to the memorization group consisted of 383 words total. The flashcards presented to the elaboration group consisted of 796 words.

Once participants had been presented with each flashcard one time, they were directed to the distraction phase of the experiment. This phase of the experiment consisted of a task designed to clear working memory. The control group completed the distraction task immediately after reading the article.

The distraction task consisted of 10 questions. Participants were asked to complete as many questions as possible in 1 minute. They were able to see the timer count down from 60 seconds while completing the task. Although most participants were able to complete about seven of the demographics questions, none of the participants were able to fully complete the questionnaire.

After 1 minute exactly, participants were automatically redirected to the testing phase of the experiment. The test consisted of 14 questions designed to test comprehension for the information provided in the reading material. Half of the test questions were designed to assess shallow (factual) understanding of the material (e.g., “What symptoms are commonly exhibited in people with hoarding disorder [HD]?”). The other half of the test questions were designed to assess deep (meaningful) understanding of the material (e.g., “Do people with obsessive compulsive disorder [OCD] respond better to SSRI medications or SNRI medications?”). Questions 1, 3, 7, 9, 11, and 13 assessed deep level knowledge. Each question was presented along with four possible answers. Participants were instructed to choose the best answer available. All questions were presented in chronological order matching how the associated concepts were introduced in the read and study phases of the experiment. Participants were given an unlimited amount of time to complete the test.

Upon completing the test, participants were directed to a screen declaring that they had completed the research study. Participants were informed that there actually was no minimum score requirement. No participants were required to restudy the material or retake the test, regardless of their score on the test. At the end of the survey, participants were presented with their test score, and were able to review their performance for each question.

Results

The items were initially inspected to insure reliability of the test. A binomial test showed that items 2 (p correct = .072, p < .001) and 12 (p correct = .124, p = .002) were significantly below

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<th>FIGURE 1</th>
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<td>1a. What are typical symptoms of HD?</td>
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For example, if a person with HD had a pair of shoes that no longer fit, that individual would have difficulty giving away or disposing of those shoes.

Abbreviations: ADHD: Attention Deficit Hyperactivity Disorder  CBT: Cognitive Behavioral Therapy  HD: Hoarding Disorder  OCD: Obsessive Compulsive Disorder
chance. For both questions, participants reliably selected a wrong answer that was very similar to the correct option. These two shallow items were removed from further analysis. Additionally, because all test questions were matched with specific flashcards, the flashcards associated with the removed questions were also removed from all proceeding analyses of study time and processing time.

**Test score.** A one-way-between-subjects Analysis of Variance (ANOVA) was used to assess the difference in the mean proportion of correct answers on the test between the groups. All assumptions of normality were met. The test indicated a difference between groups: $F(2, 94) = 17.09, p < .001, \eta^2 = .267$. Tukey’s pairwise comparisons showed that there was no difference between the elaboration ($M = 0.58$, $SD = 0.17$) and the memorization groups ($M = 0.68$, $SD = 0.14$), $t(62) = 1.33$, $p = .56$, Cohen’s $d = 0.34$, but the control group ($M = 0.40$, $SD = 0.17$) scored worse than the elaboration group, $t(68) = 4.50$, $p < .001$, Cohen’s $d = 1.08$, and the memorization group, $t(58) = 5.62$, $p < .001$, Cohen’s $d = 1.45$.

Furthermore, the question types were inspected for differences. A mixed-design 2 (question type) x 3 (study strategy) factorial ANOVA was used to examine the differences between questions meant to assess shallow and deep levels of understanding, and how these differences were moderated by the assigned study method. All of the assumptions for this test were met. The interaction between question type and study method yielded an $F$ ratio of $F(2, 94) = 3.55$, $p = .033, \eta^2 = .07$.

Post-hoc tests were conducted for the data presented in Figure 3 using Scheffe’s method for complex comparisons (Klockars & Hancock, 2000; Scheffe, 1970). For the deep questions, $F(1, 68) = 1.95, p = .167, \eta^2 = .03$, the elaboration group ($M = 0.48$, $SD = 0.16$) was not able to outperform the memorization group ($M = 0.51$, $SD = 0.14$). However, for shallow questions, $F(1, 68) = 4.85, p = .03, \eta^2 = .07$, the elaboration group ($M = 0.8$, $SD = 0.2$) outperformed the memorization group ($M = 0.62$, $SD = 0.26$). There was no difference between the control group for the shallow questions ($M = 0.45$, $SD = 0.25$) and the control group for the deep questions ($M = 0.32$, $SD = 0.18$): $F(1, 68) = 1.25, p = .268, \eta^2 = .02$.

**Study time.** All study time calculations consisted only of data from the memorization and elaboration groups (the control group did not study). Study time was defined as the total amount of time spent reviewing the flashcards. The study time data was collected automatically using the meta data function in Qualtrics. Study time was measured in seconds (s).

A between-subjects $t$ test was used to assess the differences in study time between the two groups. Levene’s test was not significant, $F(1, 68) = 3.19, p = .08$, indicating that the assumption of homogeneity of variances was met, but there was a positive skew in the distribution. A natural log transformation of the data resulted in a normal distribution of the results. The $t$ test indicated that the elaboration group ($M = 370.49$ s, $SD = 228.80$ s) studied longer than the memorization group ($M = 249.52$ s, $SD = 154.84$ s), $t(68) = 2.52, p = .014$, Cohen’s $d = 0.603$.

Processing time was measured in seconds per word (spw). Processing time was calculated by dividing study time by the number of words in the study material. A between-subjects $t$ test was used to assess the difference in processing time between the two groups. Levene's test was not significant, $F(1, 68) = 2.74, p = .10$, indicating that the assumption of homogeneity of variances was met, but there was a positive skew in the distribution. A natural log transformation of the data resulted in a normal distribution. The $t$ test indicated that the memorization group ($M = 0.78$ spw, $SD = 0.47$ spw) spent more time processing the information than did the elaboration group ($M = 0.52$ spw, $SD = 0.34$): $t(68) = 2.96, p = .004$, Cohen’s $d = 0.71$.

Although the elaboration group spent more total time studying, the memorization group spent more time per word processing the study material. See Figure 4 for a graphical comparison of study time and processing time measurements for the two groups.
Discussion
The results supported our hypotheses that the elaboration group would study longer and process the study materials more efficiently than the memorization group. These results uphold the general understanding that, although elaboration takes more time to carry out than memorization (Hilgard et al., 1953), elaboration is more efficient (Karpicke et al., 2009; Roediger & Karpicke, 2006). The elaboration group outperformed the control group, but not the memorization group. The elaboration group scored better than the memorization group on the shallow questions, but surprisingly, not the deep questions.

The findings that the elaboration group did not perform better than the memorization group on deep questions is in contrast with a plethora of literature that has demonstrated the superiority of meaningful learning when compared to memorization (Ausubel, 2012; Bower et al., 1969; Bradshaw & Anderson, 1982; Craik & Tulving, 1975; Karpicke & Blunt, 2011; Mayer, 2002). Because students tend to study until they reach a level of understanding that they believe will allow them to achieve a desired level of performance (LaPorte & Nath, 1976), the lack of control over study time could have contributed to the lack of a difference between study strategies. It is also worth noting that study time and processing time exhibited an inverse relationship. A second experiment was needed to further delineate the individual effects of study time and processing time on test performance.

Experiment 2
In Experiment 1, the effects of total time and processing time were confounded with study strategy. However, based on the results in Experiment 1, we could estimate reasonable amounts of study time students would use to prepare for a test of the materials. With that information, Experiment 2 controlled study time and processing time in order to examine them independently. Experiment 2 used the same reading material, flashcards, distraction task, and test questions as used in Experiment 1. However, study time was controlled. Participants in the elaboration and memorization conditions were assigned to a brief (7.5 minutes) or extended (15 minutes) study period. Also, processing time was controlled by timing the presentation of flashcard slides. We hypothesized that (H1) participants in the elaboration condition would perform better on the test than participants assigned to the memorization condition. We also expected that (H2) participants in the elaboration condition would perform better on the slides. We hypothesized that (H3) participants assigned to a brief (7.5 minutes) study period. Also, processing time was controlled by timing the presentation of flashcard slides. We hypothesized that (H4) participants assigned to a brief (7.5 minutes) study period. Also, processing time was controlled by timing the presentation of flashcard slides. We hypothesized that (H5) participants in the extended study condition would score better than participants in the brief study condition. Third, we hypothesized that (H6) there would be no interaction between study time and study method.

Method
Participants. The sample consisted of 121 undergraduates from the same university as Experiment 1. Two participants in this experiment were removed because their scores on the comprehension test were significantly below chance (12.5%). These were the only participants in either of the experiments to score below 25%, indicating that they might not have studied, or might not have understood the task.

The sample represented a cross section of majors offered at the university. Participants were mostly White (84.6%) women (n = 92) between 18 and 37 years old (M = 20.8, SD = 2.9). The rest of the sample consisted of 29 men, and the ethnicities making up the rest of the sample were 4.1% African American, 1.7% Middle Eastern, and 0.8% Hispanic. Anyone who participated in Experiment 1 was not eligible to participate in Experiment 2. Participants were awarded class credit for participation.

Materials and procedure. As with Experiment 1, the entire procedure was conducted entirely within an online Qualtrics survey. Experiment 2 consisted of the same four phases completed in Experiment 1: (a) read, (b) study, (c) distraction, and (d) testing. The same materials used in Experiment 1 were used in Experiment 2. Participants were randomly assigned to study flashcards meant to promote memorization or elaboration for a brief (7.5 minutes) or extended (15 minutes) study period. Data collection continued until each group contained at least 30 participants.
The read phase of Experiment 2 did not change from Experiment 1. The study phase for Experiment 1 differed from Experiment 2 in that the flashcards were presented for a controlled amount of time by the Qualtrics program. To make sure that participants were attending to the flashcards, they were required to check in at random intervals during the presentation of the study material. A check-in trial simply consisted of a flashcard explaining that participants must click forward to continue studying.

The length of time each flashcard was presented was determined by the number of words on the flashcard (i.e., processing time). Processing time was determined by calculating the amount of time it took the elaboration group in Experiment 1 to read the flashcards. The elaboration group was used as the baseline for total study time because they had the shorter processing time in Experiment 1. Hence, this group provided a more accurate measure of what was likely the amount of time necessary for participants to successfully read and comprehend the flashcards.

A mean processing time of .50 spw was used as a baseline for determining the study time for the brief study condition. To ensure that none of the participants would have trouble reading the material, a 1-minute buffer was added to the total study time. This method resulted in a study time of 7.5 minutes (0.57 spw) for the brief study condition.

A reading time of 0.57 spw amounts to a reading pace of 105.2 words per minute (wpm). Given that college students generally read at a pace of about 300 wpm (Carver, 1992; Taylor, 1965), the 7.5-minute study time was not expected to affect participants’ ability to read and comprehend the flashcards. Although the brief study condition was likely able to read all of the flashcards without difficulty, the 7.5-minute study time limit was expected to limit additional processing of the material that might occur beyond control of the experiment.

The study time for the extended study condition was determined by doubling the study time allowed for the brief study condition. The extended study condition was given 15 total minutes to study the flashcards. This amounted to a processing time of 1.14 spw.

The flashcards for the elaboration condition contained a total of 413 more words than the flashcards for the memorization condition. For the brief study condition, this difference in volume of study material resulted in a total study time for the elaboration condition that was 235.41 s longer than the total study time for the memorization condition.

At the beginning of the study phase, participants in the memorization condition completed an additional puzzle task to account for the total time difference between conditions. This allowed for both of the study strategy conditions to have the same amount of time between (a) reading the article and taking the test and (b) studying the flashcards and taking the test. The puzzle task required participants to complete a difficult word search entitled, “Getting to Know Indiana.” The word search had 50 hidden words all centered around the state of Indiana. This theme was chosen because there was no information that would likely interfere with the information presented in the article. When the time ran out on the puzzle task, participants were automatically redirected to the memorization flashcards. None of the participants were able to complete the entire word search before the time ran out.

Upon completion of the study phase, participants were automatically redirected to the distraction phase of the experiment. The distraction task consisted of the same questions used in the distraction task for Experiment 1. After participants completed as many questions as possible in 1 minute, they were automatically directed to the testing phase.

The testing phase consisted of the same test that was administered to participants in Experiment 1. As in Experiment 1, participants were informed during the briefing that if they did not score a 75% on the test they would be required to restudy the material and retake the test. No participants were actually held to this standard. When participants completed the test, they were redirected to a screen that informed them that they had successfully completed the study and thanked them for their participation. Participants were able to see their test score and review their performance after completing the entire survey.

Results
As with Experiment 1, each test item was inspected for reliability. The binomial test followed the same pattern as Experiment 1: Items 2 (p correct = .125, p < .001) and 12 (p correct = .135, p = .001) were significantly below chance. Once again these items were removed from the proceeding analyses of test performance.


Test scores. A between-subjects 2 (study time) x 2 (study strategy) factorial ANOVA was used to assess the test performance of the four different conditions. Because study time was dictated by the predetermined processing time coefficient, and the total number of words varied systematically based on study strategy, a Weighted Least Squares (WLS) correction was used to control for the difference in total study time between the elaboration and memorization conditions. The WLS correction applied weights to the data based on total study time.

All of the assumptions of the ANOVA were met. The main effect for study time yielded an F ratio of $F(1, 117) = 13.42$, $p < .001$, $\eta_p^2 = .103$, indicating that the extended study condition ($M = 0.63$, $SD = 0.13$) outperformed the brief study condition ($M = 0.53$, $SD = 0.13$) on the test. The main effect for study strategy yielded an F ratio of $F(1, 117) = 13.48$, $p < .001$, $\eta_p^2 = .103$, indicating that the elaboration condition ($M = 0.62$, $SD = 0.14$) outperformed the memorization condition ($M = 0.53$, $SD = 0.13$) on the test. As can be seen in Figure 5, there clearly was no interaction between study time and study strategy; $F(1, 117) = 0.06$, $p = .812$, $\eta_p^2 = .000$.

As in Experiment 1, the question types were inspected for differences. A mixed-design 2 (question type) x 2 (study strategy) factorial ANOVA was used to assess the differences between the deep and shallow questions, and how these differences were moderated by the assigned study method. Levene’s test indicated that the assumption for homogeneity of variances was not met, $F(7, 1432) = 52.64$, $p < .001$. To account for the lack of normality, the main effects were assessed using the Kruskal-Wallis test. The main effect for question type, $H(1) = 44.03$, $p < .001$, indicated that the shallow questions ($M = 0.68$, $SD = 0.46$) were easier than the deep questions ($M = 0.5$, $SD = 0.5$). As can be seen in Figure 6, there were no interactions between the question type and study strategy, $F(1, 116) = 1.26$, $p = .26$, $\eta_p^2 = .01$, study time, $F(1, 116) = 1.77$, $p = .186$, $\eta_p^2 = .02$, or for the interaction between study time, study method, and test question type, $F(1, 116) = 0.13$, $p = .72$, $\eta_p^2 = .00$.

Discussion

The results supported our hypothesis that, when processing time was controlled, increasing total study time would result in better test scores. The results also supported our hypothesis that the elaboration condition would score better on the test than the memorization condition. Additionally, the results supported our hypothesis that there would be no interaction between study time and study method.

The findings from this study support a large literature indicating that elaboration leads to better test performance than memorization (e.g., Adler & Van Doren, 1972; Artis, 2008; Bower, 1970; Bower et al., 1969; Carlston, 2011; Karpicke & Roediger, 2008), and that more study time leads to better test performance (e.g., Cooper & Pantle, 1967; d’Ydewalle, Swerts, & Corte, 1983; Ebbinghaus, 1885; Karpicke, Butler, & Roediger, 2009; Keith, 1982; Kornell & Bjork, 2007; Landrum et al., 2006). The specific contribution in this experiment is that the study time and study strategy factors operate independently and are about equal in impact on test performance.

General Discussion

Previous research has concluded that study time is only effective to the extent that elaborative study methods are utilized (Cooper & Pantle, 1967). This sentiment has been echoed by Bower et al. (1969), Craik and Lockhart (1972), and Roediger and Karpicke (2006), all of whom concluded that test performance is largely based on the applied...
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depth of processing. The current study posits that processing time is a third variable bridging the effects of study time and study strategy. When processing time is not controlled, the effects of study time and study strategy become entangled. When processing time is controlled, study time and study strategy are individuated.

Given the systematic differences in total study time and processing time between the two study methods, the adjustments made by the students were likely made in reference to judgments of processing fluency (Karpicke et al., 2009). In this light, the results from Experiment 1 suggest that participants found the elaboration flashcards easier to read. The improved readability of elaborative study materials appears to provide meaningful learning strategies with an efficiency advantage over memorization (e.g., Bower et al., 1969; Karpicke & Roediger, 2008; Kember et al., 1995).

The shallow questions were easier than the deep questions, but the elaboration condition did not outperform the memorization condition on either of the question types. These findings suggest that studying the elaboration flashcards did not necessarily result in a more meaningful level of understanding than studying the memorization flashcards. If the participants were using the same strategy to study both sets of flashcards, information gained from the applied examples provided in the elaboration condition might have failed to translate to the conceptual comparisons assessed in the deep questions. In Experiment 1, the provided examples promoted the elaboration condition’s memory for factual information. Although the results for Experiment 2 followed this general trend, the elaborative advantage was not related to question type. From this, we can conclude that the elaborations in this study contributed to strengthening the memory for the studied information, but might not have provided a platform for exhibiting a more holistic understanding of the studied material (e.g., Ausubel, 2012; Mayer, 2002).

Additionally, the study materials for the elaboration groups contained only one elaboration per studied concept. In Experiment 1, this proved to be too weak of a manipulation to differentiate the effects of the two study strategies. An increase in the difference of the number of elaborations between the groups might have improved the power of the manipulation. Alternatively, the lack of control over study time might have contributed variance to the results that could not be accounted for by controlling the study strategy.

Although this study observed the differences in elaborative and memorization study strategies, there was no measure of what mental strategies the participants were actually implementing. As such, it is possible that participants in either group could have developed their own elaborations, or simply attempted to memorize all of the material. The differences between the processing times for elaboration and memorization groups suggest that the study methods were reliably different. Future research could clarify these differences by having participants record their study activity, or report the strategies they use.

Another important factor to consider is control over the volume of the provided study material and processing time. Experiment 2 was only able to apply a secondary statistical control to account for differences in processing time between conditions. For the manipulation to control for processing time, the amount of material being studied by the groups being compared must be equal. This can be difficult to accomplish without diluting the less meaningful material with unrelated information, or making the material difficult to read. In other paradigms, this issue of control has been managed by having participants study qualitatively different word lists (e.g., Bower, 1969; Karpicke & Roediger, 2008). This method serves as a natural control for the third variable of processing time, but also does not allow for the differentiation between study time and processing time. That being said, although it may be difficult to accomplish, future studies could attempt to develop study materials that are equivalent in the amount of information being processed.

Although a variety of study methods can be considered elaborative or meaningful (e.g., Ausubel, 2012; Mayer, 2002), this study only focused on one form of elaboration (i.e., applied examples). Further confirmation is necessary to establish that the findings associated with one type of elaboration can be generalized to every type of elaboration.

One issue that the current research does not address is when it may be best to implement the implications of this study with students. Previous research (e.g., Christopoulos et al., 1987; Dellucchi et al., 1987) has reported that students increase study time as they progress in their formal education from middle school into college. However, a number of researchers have found that the strategies used by these students do not seem to evolve much. The research here suggests that at some point(s) students should be strongly encouraged to adopt more effective learning/study strategies.
This may require both explicit instruction and the
use of assigned tasks that are difficult for students
to complete without using elaborative strategies.
The current research did not address when this
should be done.

Conclusions

The purpose of this study was to determine the
independent roles of study time and study method
on test performance. Our results showed that elaboration was a more efficient study strategy
than memorization. Furthermore, this study dem-
strated that the effects of study time and study
strategy exhibited a separate, but relatively equal,
influence on test performance.

Study time is an important factor relating to
academic performance, but how that time is spent
is generally considered more important for predict-
ing academic performance (Delucchi, Rohwer,
& Thomas, 1987; Kember et al., 1995; Schuman
et al., 1985). Although there appears to be some awareness among college students that some study
strategies are more effective than others (Tang,
1994), students continue to rely heavily on the
use of inefficient and unproductive memorization
strategies (Christopoulos et al., 1987; Entwistle
& McCune, 2004; Karpicke et al., 2009). In some
cases, this may be a product of the inability of undergraduates to effectively execute these study
strategies (Tang, 1994). In other cases, the exhibited naivety of these students may be propagated by
a widespread "illusion of competence" (Karpicke
et al., 2009, p. 478) when memorizing study material.

The most effective study strategies take advantage of the effects of study time and study method.
To maximize efficiency and develop a more in-depth understanding of the learning material, students should focus on implementing meaningful learning strategies such as elaboration. What is still unclear is at what point students should be strongly encouraged to adopt more effective learning/study strategies.

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Author Note. Zachary J. Cole, https://orcid.org/0000-0002-0692-0692-5739, Ball State University; and Darrell L. Butler, https://orcid.org/0000-0001-7688-2861, Ball State University.

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Correspondence concerning this article should be addressed to Zachary Cole, Department of Psychology, University of Nebraska-Lincoln, 325 Burnett Hall, Lincoln, NE 68508.
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