STUDY STRATEGY AND EFFORT

HOW DOES STUDY STRATEGY INFLUENCE THE WAY STUDENTS EXPERIENCE EFFORT?

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Lay Abstract

Rereading notes or textbooks is a popular way for students to study, but it is less effective if a student wants to remember the material over a longer period. Retrieval practice, or the act of recalling information from memory, is a less popular strategy, but is effective for long-term retention. Clearly, students do not always select the effective strategy, and one explanation is that there could be a difference in how students feel about these strategies. To investigate this issue, I conducted two studies to examine whether rereading and retrieval differ in terms of how they are experienced, and how effort correlates with test performance. The findings show the importance of using a more specific definition and methodology to measure student experiences like cognitive effort when conducting research.

Abstract

Understanding how and why students engage in certain strategies over others remains an important question. The choices that people make are influenced by their experiences, so one possible explanation for the discrepancy in popularity between rereading and retrieval could be that these strategies may differ in terms of how they are subjectively experienced.

In the two present studies, we investigate whether varying study strategy leads to systematic changes in student experience, and whether various facets of cognitive effort correlate with performance on a final memory test. In Study I, participants (n=245) were randomly assigned to study a passage using either rereading or retrieval and reported on their experience of cognitive effort as well as their experience of flow (i.e., DEC) while studying. Participants' memory of the passage was tested using a multiple-choice quiz and retrospective motivation was measured. Task difficulty was significantly higher in the retrieval than in the restudy condition, but there were no significant differences between the two conditions in participants' felt effort or their fatigue. Task difficulty and fatigue were significantly negatively correlated with test performance, while felt effort had no correlation. Participants in the rereading condition performed better than those in the retrieval condition on the final memory test.

To further determine whether effort correlates with performance on the final memory test, Study II (n=53) followed the same methodology as Study I, but in addition to writing an immediate test, participants returned one week later for a delayed memory test. There were no significant differences between strategies for any facets of effort, but felt effort was significantly positively correlated with immediate test performance in the

retrieval condition. These studies show the importance of disentangling the different facets of cognitive effort and highlight the need for a more specific definition of effort in the literature.

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List of Abbreviations and Symbols

M- mean
SD- standard deviation
DEC- deep, effortless concentration (flow)

Declaration of Academic Achievement

I have authored all of the material presented in this thesis, with contribution from lab members and advisors.

Caitlin Reintjes was the primary author of the thesis, designed the two studies presented here, analyzed the data, and interpreted the findings.

Jeremy Marty-Dugas helped guide the design of the study, assisted with analysis and interpretation of findings, and provided input on this final written document.

Veronica Cui assisted in writing test questions for Study I.

Joe Kim and **Faria Sana** provided input throughout the research process.

Introduction

In a university setting, the time that a student spends outside of lectures studying for their assessments is of critical importance for learning and test performance (Stinebrickner & Stinebrickner, 2008). One study indicates that first-year undergraduates spend an average of four hours per day studying (Richardson et al., 2019), and another shows that students study for 75 minutes for each 60 minutes spent in a lecture hall (Welker & Wadzuk, 2012). Clearly, university students have many demands on their time, but research indicates that they may not be using their time spent studying in an effective way. Although various individual-difference factors, such as working memory (Berkowitz et al., 2022) and motivation (Smith & Smith, 2002) may influence academic performance, the way in which a student studies is crucial for their academic achievement (Dunlosky et al., 2013).

There are many different strategies that university students employ while preparing for exams, including rereading notes (Carrier et al., 2003; Karpicke et al., 2009), rewatching recorded lectures (Miltiadous et al. 2020), highlighting material (Yue et al., 2015), using keywords (Dunlosky et al., 2013), or implementing retrieval practice (Karpicke et al., 2009). However, these strategies are not equal in efficacy, and the strategies that a student selects may influence their learning outcomes and test performance (Dunlosky et al., 2013, Roediger & Karpicke, 2006b). A strategy like rereading class notes or textbooks may be popular among students because they typically do not have to be taught how to do it, and it is less time consuming than other strategies students could employ (Dunlosky et al., 2013). Despite these perceived benefits, previous studies have shown that rereading information is not an effective

method for enhancing long term retention compared to practicing retrieval of the studied information (Callendar & McDaniel, 2009; Karpicke et al., 2009, Karpicke & Roediger, 2007; Roediger & Karpicke, 2006b).

Retrieval practice involves recalling information from memory (Agarwal et al., 2012; Butler & Roediger, 2011; Karpicke et al., 2009). This can be done through activities such as repeated practice of word pairs, use of flash cards, or writing down what one already knows without referring to notes (Karpicke & Roediger, 2008; Roediger & Karpicke, 2006b). When individuals study for equal amounts of time, those who retrieve content they are presented with will retain the information better than those who reread it (Gates, 1917; Roediger & Butler, 2011), suggesting that retrieval practice is more effective and more time efficient. This effect is particularly pronounced for long-term retention of the material (Dunlosky et al, 2013; Karpicke & Roediger, 2007; Roediger & Karpicke, 2006a, 2006b); a seminal study of undergraduate students found that the efficacy of retrieval was not seen when writing a test five minutes after a study period, but that retrieval was more effective than rereading on delayed tests written one week later (Roediger & Karpicke, 2006b).

When considering the differences in performance for long term retention and time efficacy between the strategies, it becomes clear that after seeing the benefits of retrieval practice over rereading, undergraduate students should be choosing to use retrieval when reviewing course material. However, not only do these two techniques differ in *efficacy*, but they also differ in *popularity*. Undergraduate students continue to rely on the less effective strategy of rereading, with 84% indicating that they use rereading as a study strategy, and 55% stating it is their preferred method to study

content (Karpicke et al., 2009). Despite retrieval being more effective, only 11% of students indicate that they implement retrieval practice into their studying (Karpicke et al., 2009).

Given that most students aim to succeed throughout their university career, and effective studying is critical for academic achievement, one might expect that undergraduates would select study strategies based on their efficacy; however, given the difference in popularity between the strategies, it could be that students take additional factors, aside from effectiveness, into consideration when making decisions about study strategies. For example, one possibility is that these study strategies differ in terms of students' subjective experience while they are studying. Subjective experiences have frequently been shown to influence a person's decision-making across multiple domains (Ralph et al., 2020; Slovic et al., 2007). To investigate this possibility, in the present studies, I investigate whether subjective effort while studying differs as a function of the strategy used. In particular, I assessed participants' subjective experience of effort and flow (i.e., deep, effortless concentration- DEC).

Effort

One explanation for the difference in popularity between retrieval practice and rereading could involve the amount of cognitive effort a student is required to expend for each strategy. Cognitive effort is considered to be a finite, limited resource that is invested or exerted during a difficult task, and is often associated with negative affect (Bambrah et al., 2019; Garbarino & Ebell, 1997). In general, people seek to avoid effort and complete tasks with the minimal amount of effort that is required of them. Retrieval practice is thought to be effortful (Gardiner et al., 1973, Pyc & Rawson, 2009, Roediger

& Butler, 2011), and if this is indeed the case, the increased effort required with this method could at least partly explain why many students choose to reread their notes instead of utilizing retrieval.

Interestingly, effort has also been cited as an explanation for why retrieval is particularly effective (Roediger & Butler, 2011). The literature suggests that the amount of effort required to retrieve a certain memory is a measure of how much reprocessing is taking place, which in turn leads to better retention (Roediger & Butler, 2011). However, when effort is discussed in the literature on retrieval practice, it is unclear what specifically is meant by "effort". Effort could refer to a physiological measure (Botvinick & Rosen, 2009; Piquado et al., 2010), or something subjectively experienced by an individual (Dunn et al., 2019; Hsu et al., 2017), or another construct entirely (Shepherd, 2022). Indeed, Shepherd (2022) highlights the lack of specificity in the literature on effort in general, writing "…the construct of cognitive effort, as it is deployed in cognitive psychology and neuroscience, is problematically unclear."

This raises the question of how best to evaluate effort in the context of student studying. Since effort could be interpreted in many different ways, we first chose to evaluate subjective experiences of cognitive effort, as this is easily accessible and highly relevant to the study population of undergraduate students, who make daily choices about which study strategies to select. It is possible that physiological measures (such as pupil diameter) and the subjective experience of effort could both be reflective of the same underlying neurological process, and could therefore both be said to reflect "effort". However, it is likely that the subjective experience of effort is what most students are more likely to be consciously aware of and able to access—and thus,

this is perhaps more likely to directly influence their choice of study strategy. As such, in the present study we were specifically interested in evaluating students' subjective experiences of effort while studying. Currently, differences in effort between rereading and retrieval practice have not been evaluated in terms of students' subjective experiences of effort. Rather, it has been inferred based on differences in performance—such that those who performed better are *assumed* to have expended more effort. As such, there is a clear need for research that investigates this putative relation and elucidates the differences (if any) in the subjective experience of effort when employing these two strategies.

Measuring the subjective experience of effort

The study of effort is a nuanced topic, and it requires great care to disentangle all of its facets to evaluate claims made about effort in the literature. When measuring the subjective experience of effort there are three related, but distinct, factors to consider: 1) Task difficulty, 2) Felt Effort, 3) and Fatigue. The first facet of effort is task difficulty, which refers to how challenging an individual believes that a task is based on the inherent qualities of the task (Hsu et al., 2017). Some tasks might be viewed as quite easy (e.g., walking to the mailbox), while others are seen as quite hard (e.g., running a marathon). The second factor to consider is that of felt effort, which refers to how hard participants feel they tried while completing the task. Importantly, felt effort is distinct from how difficult participants believe a task to be (Hsu et al., 2017), as participants could choose to output a Herculean effort for an easy task, or very little effort on a demanding task. That is, even when the difficulty of a task is consistent for participants, the amount of effort that they put into it can vary—one individual could complete the task with minimal effort, whereas

another individual could complete the same task with a great deal of effort. Finally, when examining experiences of subjective effort, it is important to investigate how fatiguing or draining participants found the task to be. This measures the impact of the task and their felt effort on the individual (Hsu et al., 2017), and this is also independent of task difficulty and felt effort. For example, after expending a great deal of effort to accomplish a difficult task (e.g., climbing a mountain), one individual might feel tired and drained; however, another individual could feel invigorated by their accomplishment. Since these facets of cognitive effort are distinct, it is crucial that they are all examined and teased apart so that they are not conflated. For example, if one were to measure task difficulty only, participants' responses could be influenced by their experience of felt effort or fatigue—meaning that different facets of subjective effort could be conflated. By measuring all three of these facets, it reduces concerns about conflation because participants have the opportunity to express their experience by responding to questions about each facet in turn. As such it allows both participants and the researcher to tease apart the related, but nevertheless distinct, facets of subjective effort.

The Present Studies

As is evident from the foregoing literature, there is a clear need for greater understanding of the student experience of effort while studying, as well as of the relationship between this experience and subsequent memory. While education literature to date would suggest that retrieval is effective because it is "more effortful" than other strategies like rereading or highlighting notes (Dunlosky et al., 2013; Roediger & Butler, 2011; Endres & Renkl, 2015), there is a lack of specificity in the literature defining what is meant by this idea of "effort". Thus, in the present investigations, my purpose was two-

fold: 1) To examine whether participants' subjective experience varied as a function of study strategy, and 2) To better understand the relationship between different facets of effort and performance on a final memory test. To begin to address these goals, I conducted two studies examining students' subjective experience of studying and examining the correlation between these experiences and subsequent test performance.

In Study I, I sought to address my two goals by examining whether student experiences systematically differed when randomly assigned to use either the rereading or retrieval practice strategy, and how the student experience of effort correlates with performance. Following an initial reading of a short passage, students used their assigned strategy to study the material or retrieve the information from memory for 10 minutes (i.e., the study phase). Specifically, to address my first goal (i.e., whether student experiences differ by strategy) I assessed participants' subjective experience using self-report measures immediately after the study period. Importantly, I assessed subjective effort by disentangling the construct of effort into three distinct facets; task difficulty, felt effort, and fatigue (see Hsu et al., 2017), as this method allows us to distinguish between these three facets, thus avoiding conflating them and adding more specificity to our understanding of effort while studying.

Next, participants completed an operation span task followed by a final, multiple choice memory test. The use of the memory test was critical for addressing my second goal (i.e., determining if effort correlates to test performance). Specifically, I wanted to determine if there was a relationship between *any* of the three facets of effort and test performance, as prior work does not specify which facets of effort should-or should not-relate to better test performance. I assessed this relationship by correlating subjective

reports of effort and immediate test performance in Study I. In Study II, I assessed subjective reports of effort and both immediate and delayed test performance to account for the possibility that the relationship between effort and performance only emerges after a delay. Furthermore, in both studies, I investigated whether the relationship between effort and subsequent memory performance differs according to the strategy that a participant uses. Based on the retrieval-effort hypothesis, we might expect that there is a relationship between at least some of the three facets of effort and test performance in the retrieval condition specifically. Recall that the literature suggests that increased difficulty in retrieval leads to better test performance (Pyc & Rawson, 2009). As such, we might expect that increased task difficulty or expended effort leads to higher test scores in the retrieval condition, but not necessarily the rereading condition. It is important to separate our effort and performance analyses by strategy so that we can determine if effort differentially impacts test performance for the retrieval condition, instead of looking at the relationship between effort and performance as a whole.

In addition, I took the opportunity to collect data on participants' experience of "flow" (Csiksentmihalyi, 1975/2000), an experience that is conceptually adjacent to subjective effort, as well as their level of motivation to learn the material presented to them in the study. I first aimed to determine how two study strategies may affect a participant's flow experience. In particular, flow is characterized by the experience of Deep, Effortless Concentration (DEC; Marty-Dugas & Smilek, 2019; see also Nakamura & Csikszentmihalyi, 2002). Flow could be particularly relevant in the context of studying because a crucial aspect of DEC is the ease, or effortlessness, that participants experience when they are in flow. However, while flow has been a popular topic within

education, it has been difficult to draw clear conclusions because of conceptual and measurement issues in the flow literature (Swann et al., 2012). In the present study, we addressed this by assessing flow using measures of deep, effortless concentration (DEC; Marty-Dugas & Smilek, 2019), which allow for the experience of flow to be indexed more precisely.

It is possible that flow is a mechanism that explains why more students engage in ease-inducing strategies such as rereading. Since retrieval practice is frequently cited as more effortful than a study strategy such as rereading, it is possible that participants may report feeling less DEC when studying using retrieval practice. When in a state of flow, individuals may feel as though a task is effortless (Marty-Dugas & Smilek, 2019), and they may interpret that ease and flow as increased knowledge of the material. If this is the case, it is possible that the experience of flow is misleading students, causing them to use a less effective study strategy. However, it is first necessary to establish if there are any observable differences in these subjective experiences.

Motivation is often critical for performance across a variety of academic tasks (Ferrer et al., 2020; Lee, 2013; Prat-Sala & Redford, 2010), as well as initiating study behaviours (Stinbrickner & Stinebrickner, 2008) One possibility is that—whether independently or as a result of their experience of effort—different study strategies may differ in terms of how motivated students are to re-engage in studying behaviours after using them. Further, there is reason to believe that motivation will impact the effort students exert while studying, as motivation is related to effort in numerous domains (Hsieh, 2014; Karlen et al. 2019, Menges et al., 2016; Touré-Tillery & Fishbach, 2011).

As such, I included a retrospective measure of motivation to assess how motivation may predict students' subjective experiences while studying.

To reiterate, in the present studies my two goals are to investigate whether varying study strategy leads to systematic changes in student experience, and to determine how effort correlates to final test performance. In Study I, I address these goals by determining whether there are any differences between rereading and retrieval in terms of subjective effort and flow/DEC, and then analyze whether there are any correlations between the three facets of subjective effort and performance on an immediate memory test. In Study II, I further address the second research question by analyzing the correlation between the three facets of effort and performance for both an immediate and delayed test to account for the possibility that the relationship between effort and performance is only seen when the retrieval effect emerges.

Study I

Participants were randomly assigned to either the rereading condition or the retrieval practice condition. After completing the initial reading phase, participants rated their understanding of the passage and then studied for 10 minutes using their assigned strategy. Immediately after the study period, participants completed self-report measures for task difficulty, felt effort, fatigue, and flow. They then completed an operation span task and a final memory test, followed immediately by a retrospective measure of motivation. Any participants that did not respond to a probe or performed worse than chance on the final memory test were excluded from the final analyses.

Participants

Participants were recruited from a pool of undergraduate students in an introductory psychology class at McMaster University, and were compensated with partial course credit. Registration took place over the McMaster SONA database for psychology research. Data were collected from 277 participants, 245 of whom had usable data.

Materials and Stimuli

Effort. To assess subjective experiences of effort, we asked three questions pertaining to different facets of effort. One question assessed how difficult participants found the study phase, another asked participants for a rating of felt effort, and the final question asked about how draining participants found the study phase. Participants responded to each question and effort was measured on a Likert scale, where a score of 1 indicated that the participant never had that experience, and a score of 7 indicated that a participant always had that experience.

Deep Effortless Concentration (DEC). To assess flow experience, participants were asked to complete the Deep Effortless Concentration – state scale immediately following the study phase. The DEC- state scale is used to assess the frequency of flow experience during a particular activity. The DEC state is adapted from the Deep Effortless Concentration – Internal (DECI) and Deep Effortless Concentration – External (DECE) scales, which are used to assess trait-level individual differences in flow (Marty-Dugas & Smilek, 2019). Participants responded to each probe, and DEC was scored on a Likert scale, which ranged from a score of 1 (never) to 7 (always) (Marty-Dugas & Smilek, 2019).

Understanding. Following the initial reading of the passage, but prior to the study phase, we asked a question to assess how difficult participants found it to understand the

content of the passage. This measure of understanding used a Likert scale, which ranged from a score of 1 (not at all difficult) to 7 (extremely difficult). We measured initial difficulty in understanding the passage, as we wanted to ensure that the initial difficulty participants had in understanding the passage was distinct from the task difficulty of rereading or retrieving during the study phase, and not conflated with each other.

Motivation. Following the experiment, participants were also asked to score how motivated they were to learn the material presented in the study. Motivation was measured on a Likert scale, which ranged from a score of 1 (not at all motivated) to 7 (highly motivated).

Operation Span Task. All participants completed an Operation Span Task (Turner & Engle, 1989) as a distractor before the final memory test. Participants were presented with a series of equation-word pairs. Participants would first see a math equation on the screen. After solving it, they would have to indicate whether the given solution was true or false. A word then appeared following the equation. Once participants were exposed to all equation-word pairs, they were told to rank the words that they were presented with in the order in which they appeared.

Final Memory Test. After the distractor task, participants were given a final 30-question multiple-choice memory test to assess how much of the information they remembered from the passage.

Procedure

All participants were told to read a passage on the history of mental illness (Bridley et al., 2020; see Appendix A). Following the initial 10-minute reading phase, participants were randomly assigned to study the content of the passage for 10 minutes in either the

retrieval (recall) or rereading condition. In the retrieval condition, participants typed into a text box all of the things that they could remember from the passage before their time elapsed. In the rereading condition, participants were told to reread the passage in order to remember as much information as possible. Following the study phase, all participants completed an operation span task and final multiple choice memory test (Figure 1).

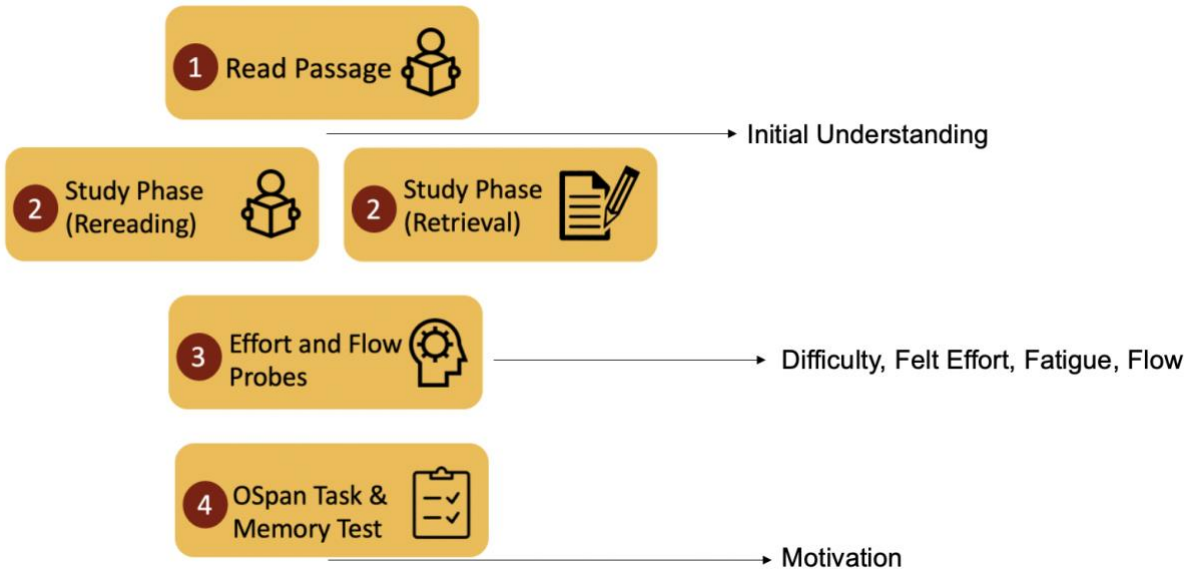

Figure 1. Overview of Methods

Results

The results for Study I are separated into two sections. The first section addresses my first goal of examining whether changing study strategy leads to systematic changes in student experience. This was done using a series of linear regressions to examine the effects of study strategy, motivation, and initial understanding on subjective experiences (difficulty, felt effort, fatigue, and flow (DEC)). The second section focuses on analysis of

data from the final memory test to determine whether the three distinct facets of effort correlate with test performance (i.e., my second goal). All analyses were completed in R (R Core Team) using the RStudio IDE. The Fisher's r to z transformations were conducted using Quantpsy (Preacher, 2002).

Part I: Subjective Experience

In this section my analyses address whether initial passage understanding, participant motivation, and condition (retrieval practice vs. rereading) had a significant impact on participants' subjective experiences during the study phase. This was done by using linear regressions to examine the impact of initial understanding, motivation, and condition for each of the three facets of cognitive effort and for DEC. Each of the linear models for the three facets of effort and DEC were tested and met the assumptions of a linear regression.

Perceived Difficulty

The linear model examined the effects of initial understanding, motivation, and study strategy (condition) on participants' ratings of how difficult they found it to study the material. The overall regression was statistically significant ($R^2 = 0.21$, $F(3,241) = 22.99$, $p < .001$). As shown in Table 1, initial understanding was a significant predictor of difficulty. Participants who found the content to be more difficult to understand after the initial reading indicated that they found the material more difficult to study during the study phase as well ($p < .001$). Motivation was not a significant predictor of difficulty, indicating that how motivated a participant was did not impact how difficult they perceived the study phase to be. The study strategy participants used was also a significant predictor of difficulty. Participants indicated that the retrieval study condition,

M=4.49, SD=1.43, was significantly more difficult than the rereading condition, M=3.67, SD=1.33 (p<.001). (Figure 2).

Table 1. Predictors of Perceived Difficulty

Effect	β	SE	95% CL		*p*
			LL	UL	
Intercept	2.76	0.32	2.13	3.40	1.04e-15***
Understanding	0.35	0.06	0.24	0.46	4.13e-09***
Motivation	-0.09	0.06	-0.21	0.023	0.12
Condition:Retrieve	0.90	0.16	0.58	1.23	1.34e-07***

Note: *$p < .05$. **$p < .01$. ***$p < .001$

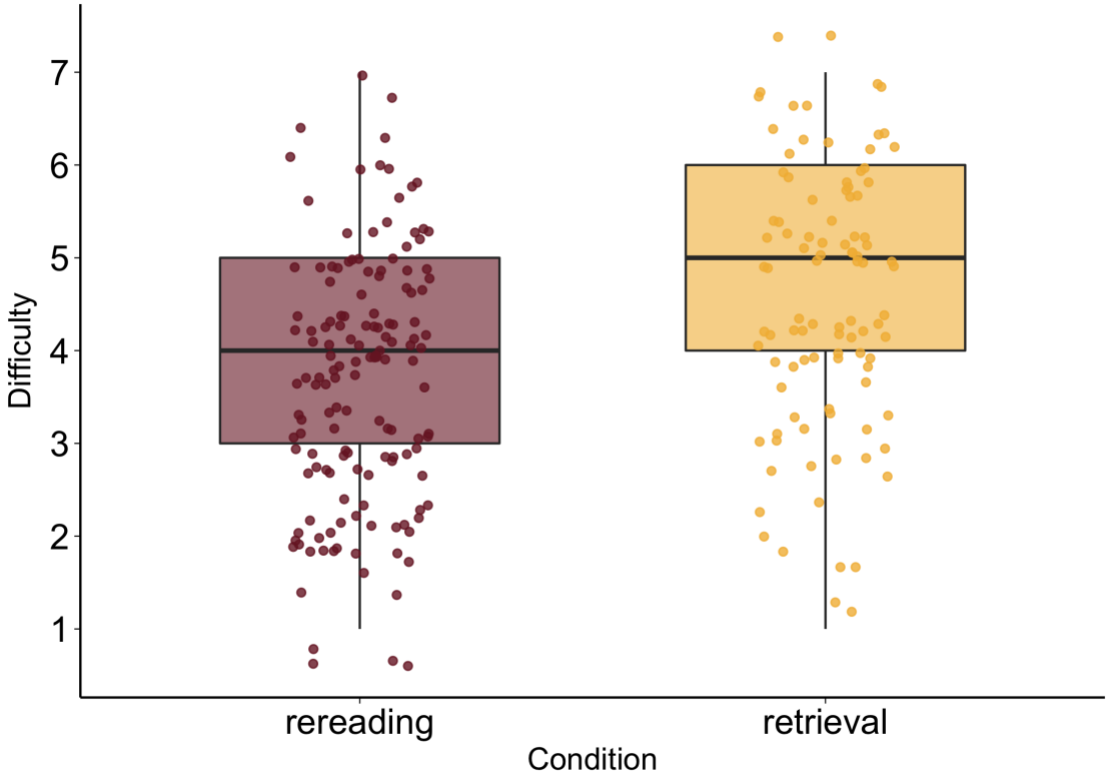

Figure 2. Difficulty by condition, rereading: M=3.67, SD=1.33, retrieval: M=4.49, SD=1.43

Felt Effort

Next, we examined the effects of initial understanding, motivation, and study strategy on participants' ratings of how much effort they felt they put into the study phase (Table 2). The overall model regression was statistically significant, (R^2 = 0.12, F(3,241) = 12.43, p <.001). Initial passage understanding was a significant predictor of felt effort (p=.02), indicating that those who had more difficulty understanding the passage during the first reading put more effort into the study phase. Motivation was also significant (p<.001), such that those who were more motivated indicated they put more effort into the study phase. When controlling for the effects of understanding and motivation, condition (i.e., study strategy) was not found to be a significant predictor of

participants felt effort. While felt effort was nominally higher in the retrieval condition (see Figure 3), the effect was on, but not under the .05 significance threshold. This result suggests that participants' effort level did not significantly differ according to the strategy they used.

Table 2. Predictors of Effort

Effect	*β*	SE	95% CL		*p*
			LL	UL	
Intercept	2.75	0.34	2.09	3.41	1.53e-14***
Understanding	0.14	0.06	0.02	0.25	0.02*
Motivation	0.34	0.06	0.22	0.47	4.60e-08***
Condition:Retrieve	0.34	0.17	-0.004	0.68	0.05

Note: *$p < .05$. **$p < .01$. ***$p < .001$

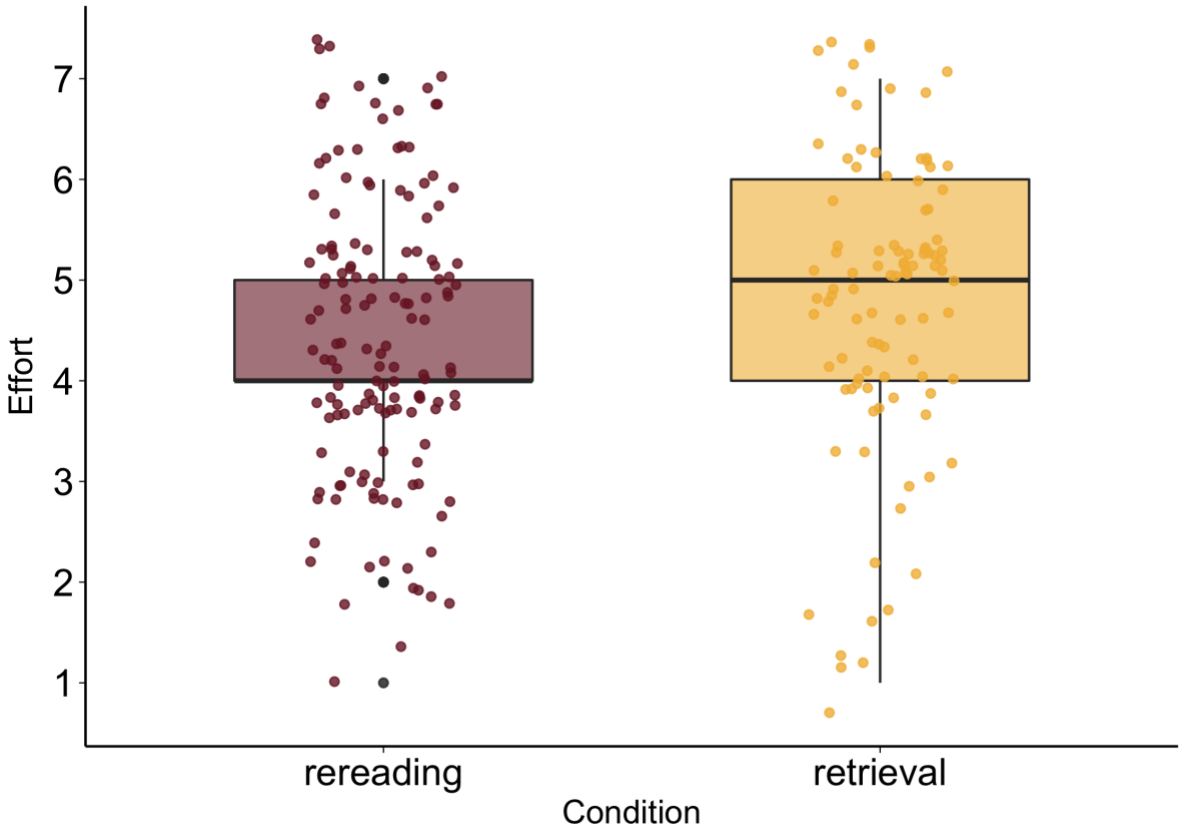

Figure 3. Effort by condition, rereading: M=4.45, SD=1.40, retrieval: M=4.58, SD=1.56

Fatigue

The next model examined the effects of initial understanding, motivation, and study strategy on ratings of how draining participants found the study phase to be (Table 3). The overall model regression was statistically significant, (R^2 = 0.08, F(3,241) = 7.70, p <.001). Initial passage understanding (p<.001) was significant, such that those who had more difficulty understanding the passage found the study phase to be more draining. Motivation was also a significant predictor of fatigue (p=.02); those who were more motivated found the study phase less fatiguing. The study strategy used during the study phase was not a significant predictor of fatigue (p=.21), indicating that neither strategy was more draining than the other (Figure 4).

Table 3. Predictors of Fatigue

Effect	β	SE	95% CL		p
			LL	UL	
Intercept	4.00	0.40	3.21	4.78	<2e-16***
Understanding	0.26	0.07	0.12	0.40	0.00033***
Motivation	-0.17	0.07	-0.32	-0.03	0.02*
Condition:Retrieve	-0.26	0.21	-0.66	0.15	0.21

Note: *$p < .05$. **$p < .01$. ***$p < .001$

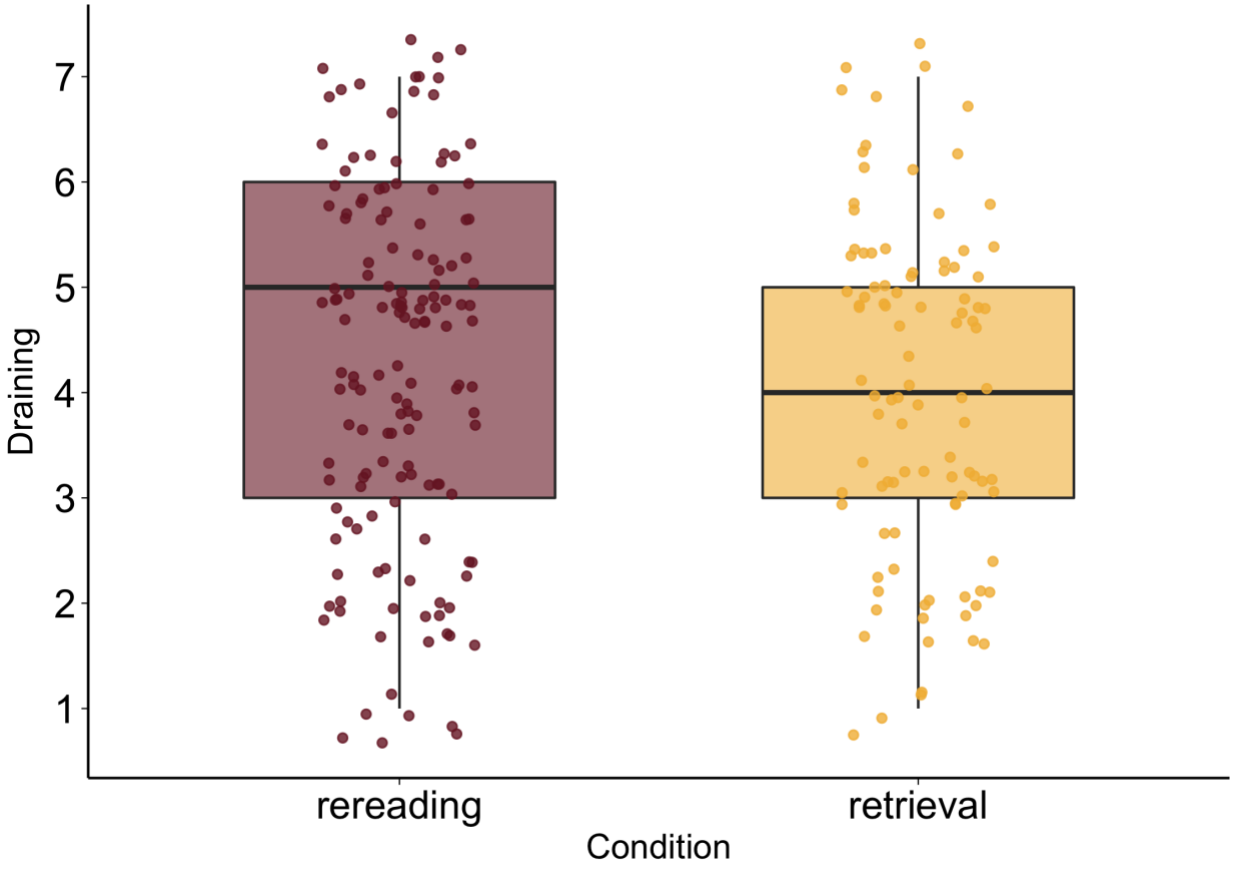

Figure 4. Fatigue by condition, rereading:* M=*4.29, SD=1.68, retrieval:* M=*3.99, SD=1.60

Flow

Finally, a linear model examined the effects of initial understanding, motivation, and study strategy on participants' experiences of flow/DEC during the study phase. The overall model regression was statistically significant, (R^2 = 0.25, F(3,241) = 27.21, p <.001). Understanding was significant (p<.001), such that those who had more difficulty understanding the passage experienced less flow. Motivation was also a significant predictor of flow (p<.001), such that those who were more motivated experienced more flow. The strategy used was not a significant predictor of flow (p=.88), meaning that

participants did not experience more flow in either study condition (Table 4, Figures 5-6).

Table 4. Predictors of Flow

Effect	β	SE	95% CL		p
			LL	UL	
Intercept	3.03	0.30	2.45	3.62	<2e-16***
Understanding	-0.20	0.05	-0.30	-0.09	0.00026*
Motivation	0.43	0.05	0.32	0.53	1.29e-13***
Condition:Retrieve	-0.02	0.15	-0.33	0.28	0.88

Note: *p < .05. **p < .01. ***p < .001

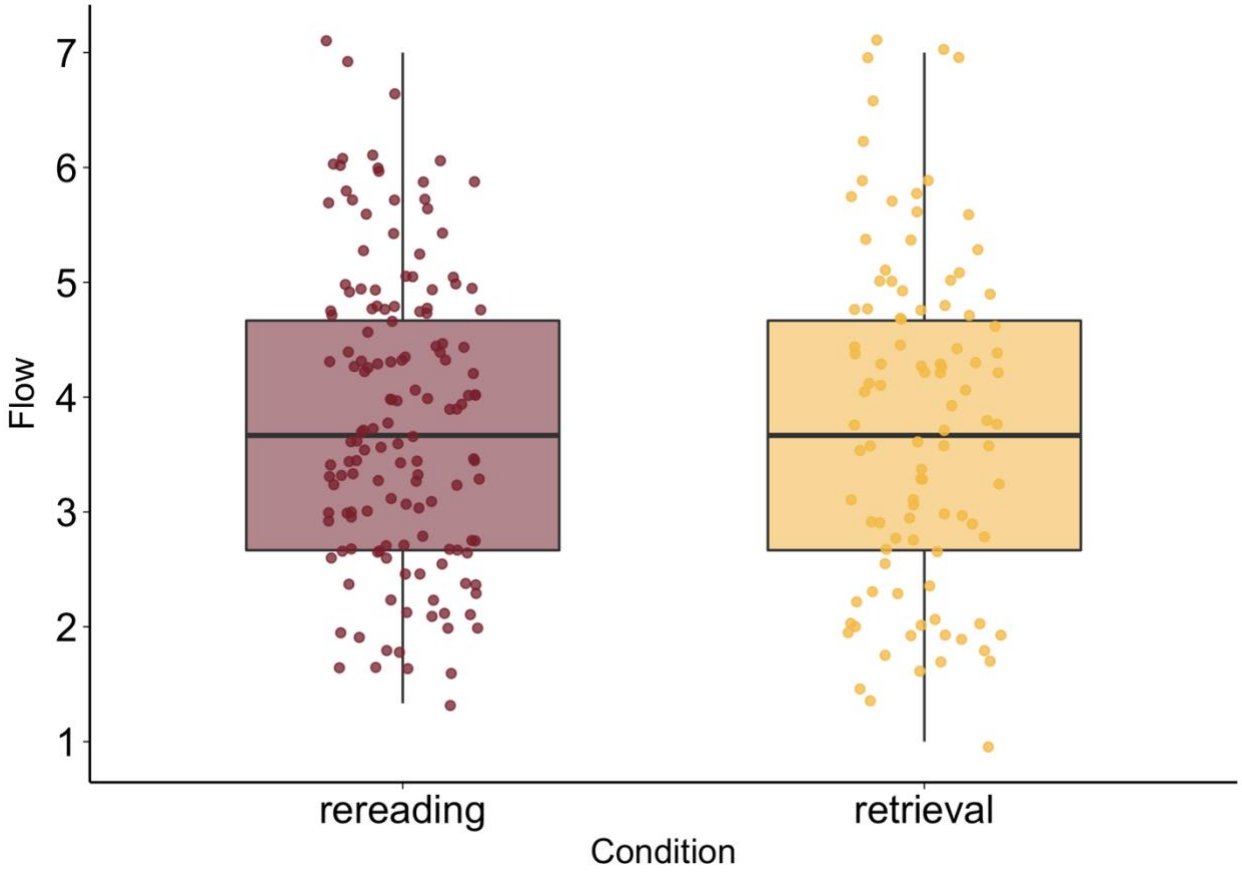

Figure 5. Flow by condition, rereading: M=3.84, SD=1.29, retrieval: M=3.8, SD=1.46

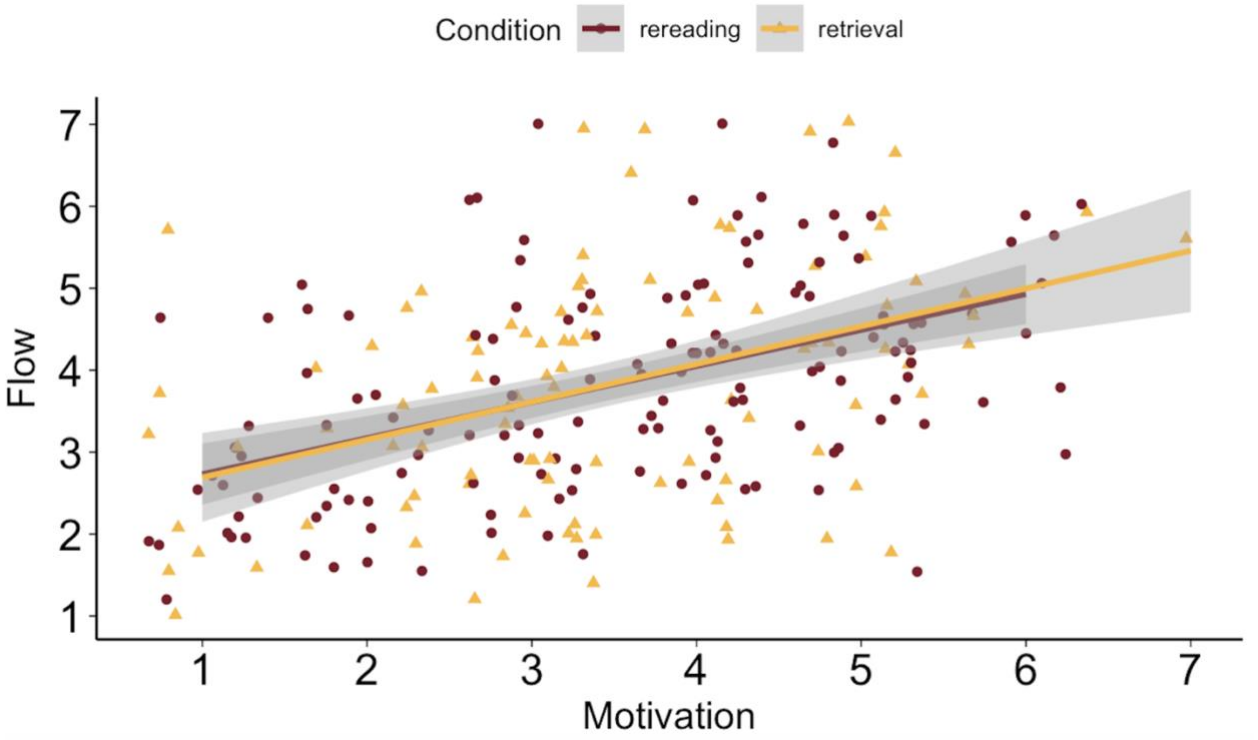

Figure 6. Flow and Motivation

Part II: Correlations Between Cognitive Effort and Performance

In this section, I present the analyses that helped to address my second goal—to better understand the relationship between the different facets of subjective effort and subsequent memory test performance. To do so, I conducted a series of correlational analyses which examined the relationship between each of the three facets of effort and performance on the final memory test, for each study condition (rereading and retrieval). While only task difficulty significantly differed at the group level, I kept the groups separate to analyze the correlations between effort and performance. This is because collapsing across the groups before calculating the correlations might obscure any differences in the nature of the correlation that occur due to study strategy. Analyzing the groups separately allowed me to determine whether the nature of the relation

between effort and performance differed according to strategy or whether the relation was similar. In addition, I examined whether there were performance differences between the two groups in terms of overall quiz performance.

Test Scores

A t-test was conducted to compare final memory test scores. The participants in the rereading condition (M=16.38, SD=4.98) performed significantly better on the final memory test than those in the retrieval condition (M=15.04, SD=4.38), p=.03 (Figure 7).

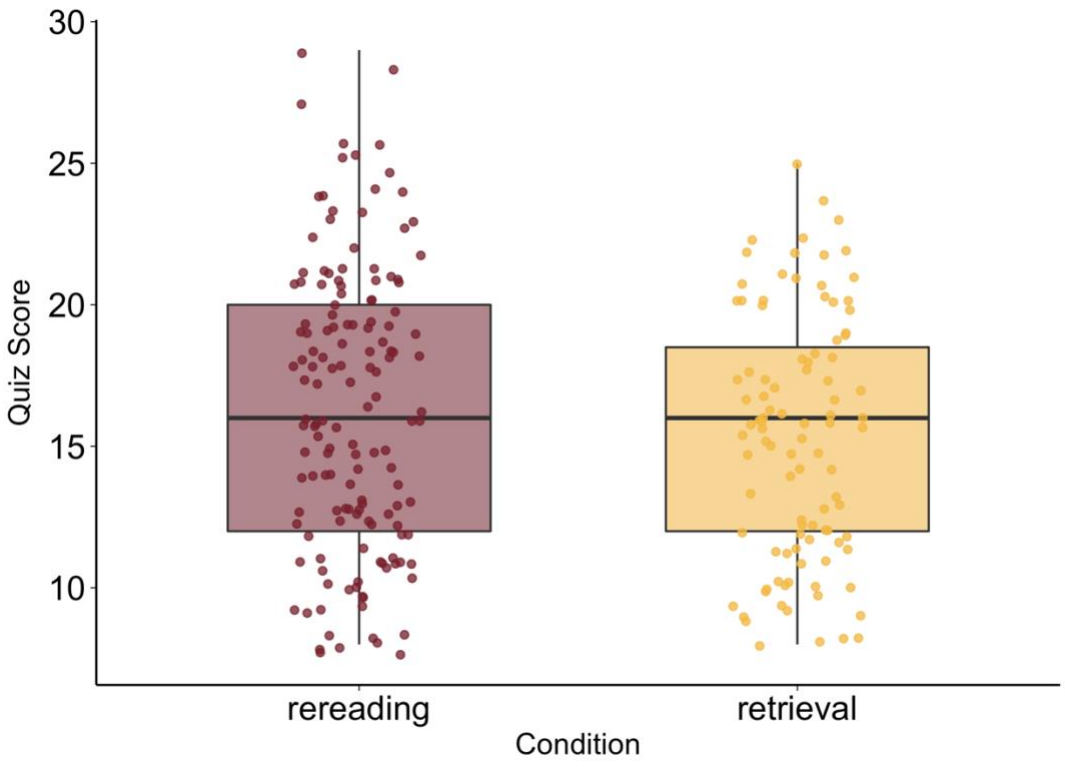

Figure 7. Memory Test Scores

Perceived Difficulty

In the rereading condition, there was a significant negative correlation between how difficult participants found the study phase and their performance on the final memory test, r(144)=-.24, p<.01. Similarly, there was a significant negative correlation between perceived difficulty and test score in the retrieval condition, r(97)=-.21, p<.05. To test whether the correlations differed across the two groups I used a Fisher's r to z transformation (Preacher, 2002). The magnitude of the correlation was not significantly different across the groups (Z = -0.24, p = .81), indicating that regardless of condition, the more difficult that participants found the study phase, the worse they performed on the final memory test (Figure 8).

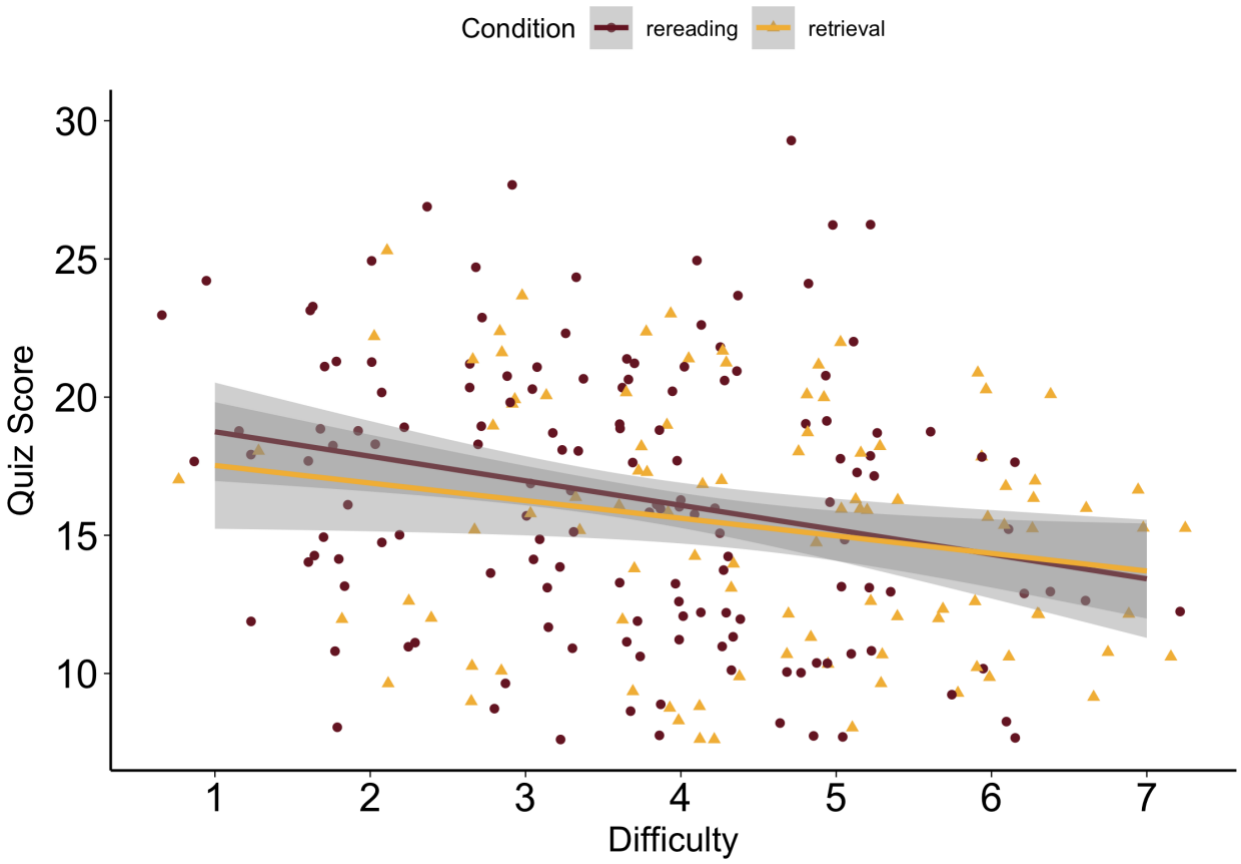

Figure 8. Difficulty and Quiz Score

Felt Effort

Another correlational analysis was conducted to examine the relationship between how much effort participants felt as though they put into the study phase and final test performance. In the rereading condition, there was no significant correlation between felt effort and test scores, r(144)=.10, p=.24. Similarly, there was no significant correlation between felt effort and test performance in the retrieval condition, r(97)=.09, p=.36. A Fisher's r to z transformation (Preacher, 2002) was used to test whether the correlations differed across the two groups. The magnitude of the correlation was not significantly different across the groups (Z = 0.08, p = .94). This suggests that regardless of the strategy used, an increase in participants' subjective felt effort did not correlate to better test performance (Figure 9).

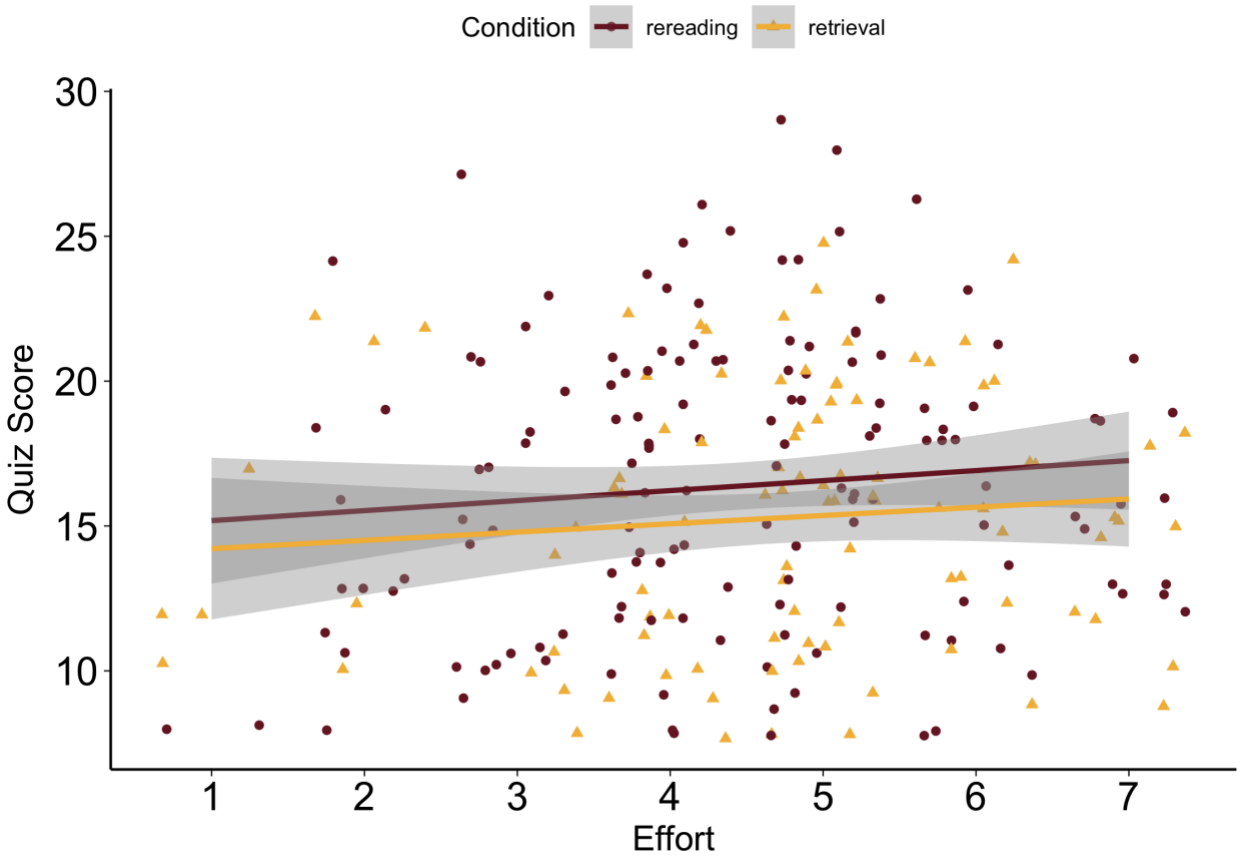

Figure 9. Felt Effort and Quiz Score

Fatigue

Finally, the relationship between how draining or fatiguing participants found the study phase and test performance was examined for each strategy using a correlational analysis. There was a significant negative correlation in the rereading condition, $r(144)=-.19$, $p<.05$, such that the more fatigued participants were, the worse they performed on the final memory test. In the retrieval condition, there was also a significant negative correlation between fatigue and test performance, $r(97)=-.27$, $p<.01$. To test whether the correlations differed across the two groups I used a Fisher's r to z transformation (Preacher, 2002). The magnitude of the correlation was not significantly

different across the groups (Z = 0.64, p = .52) suggesting that regardless of condition, the more fatigued participants were, the worse they performed on the memory test (Figure 10).

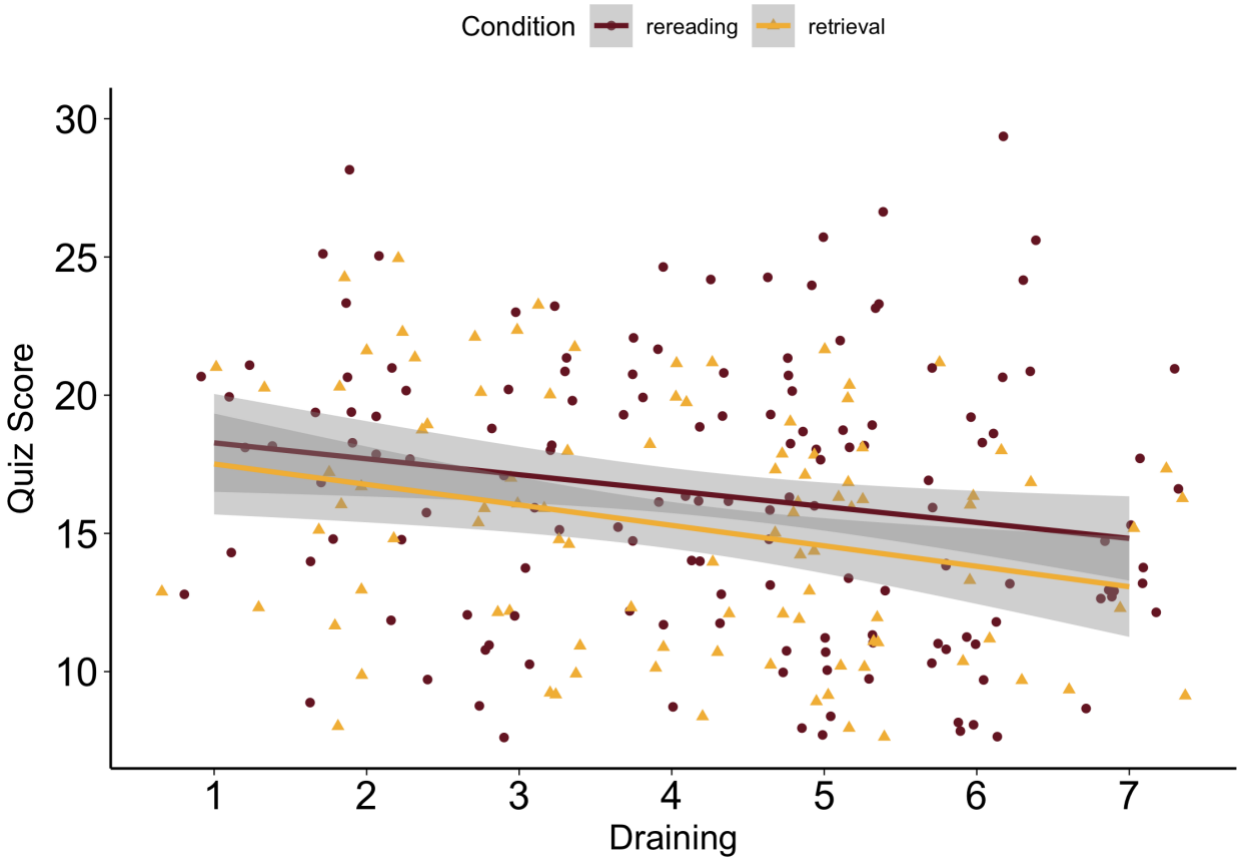

Figure 10. Fatigue and Quiz Score

Study I Discussion

In Study I, I sought to address two broad goals. I first aimed to determine whether changing the study strategy (rereading vs. retrieval) leads to systematic changes in the way that students subjectively experience effort (as evaluated by the

three facets of perceived difficulty, felt effort, and fatigue, and DEC). I also aimed to evaluate how the three facets of effort correlate to final test performance, and if this correlation varies by strategy.

To address my first research goal, I conducted a series of linear regressions to determine if initial passage understanding, motivation, and the study strategy used (rereading vs. retrieval) impacted the three effort measures- how difficult the task is, how hard the participant tried, and how fatigued they felt while expending effort to complete the task. To determine how these three facets of effort related to performance on the final memory test, I conducted correlational analyses relating each of the facets of effort to test scores.

The results indicated that participants perceived retrieval as a more difficult strategy, but there was no significant difference in terms of felt effort. This seems to suggest that while students perceive retrieval to be more difficult than rereading, this challenge does not necessitate an increase in expended effort. Further, there were no significant differences between strategies in terms of fatigue, so neither strategy (rereading vs. retrieval) seemed to be more draining to participants.

Motivation emerged as an essential factor in student perceptions of their experience. Motivation was not significantly correlated with perceived difficulty scores, suggesting that how motivated someone is does not impact peoples' ratings of the inherent difficulty of the task. However, motivation is significantly positively correlated with the amount of effort participants feel as though they expend. The more motivated a participant was to study, the greater the amount of effort they felt they put into a task.

Motivation was also negatively correlated with fatigue; the more motivated a participant was during the study phase, the less drained they would feel from completing the task.

I also performed a linear regression to assess whether DEC differed based on the strategy that participants used. There was no difference in DEC between the two strategies (rereading or retrieval). Building off of the idea that retrieval is more effortful than a strategy like rereading, I anticipated that the effortlessness involved in the passive rereading condition would lead students to experience higher levels of flow, however, this was not the case. Motivation was a critical factor in the flow model, as those who were more motivated to study experienced more flow; this finding agrees with prior research on the topic (Nakamura & Csikszentmihalyi, 2002).

With regards to my second goal, I ran a series of correlations to determine how the three facets of effort relate to test performance. I separated each correlation by strategy to test whether the relationship between the facets of effort and test performance could be specific to the study strategy that students used. There was a significant negative correlation between perceived study period difficulty and test performance, such that those who found the study phase more difficult performed worse on the final memory test. When looking at the correlations between effort expended during the task (felt effort) and quiz score, there was no significant relationship in either the rereading or the retrieval conditions. Finally, in terms of how drained participants felt, there was a significant negative correlation between fatigue and test performance in both conditions, such that those who felt more fatigued or drained following the study phase performed worse on the final memory test.

Overall, these findings suggest that participants' perceptions of difficulty vary by strategy, with retrieval practice seeming to be more difficult than rereading. However, there were no significant differences for felt effort or fatigue. Taken together, these findings allow me to clearly answer my first research question, which addresses whether or not changing the study strategy that participants use (rereading vs. retrieval practice) leads to systematic changes in student experience.

However, one finding that merits further consideration is with regards to my second research goal. I aimed to determine whether or not effort relates to performance, and if this differs by strategy. There were significant negative correlations between difficulty and test performance and fatigue and test performance, but there was no relationship between felt effort and test performance in either strategy. Based on the retrieval-effort hypothesis (Pyc & Rawson, 2009; Roediger & Butler, 2011), we might expect that increased effort correlates with increased test scores, especially in the retrieval condition, but this was not the case. However, recall that in the present study, the study condition that reread the passage performed significantly better on the final memory test than the participants who used retrieval practice.

Since it is increased effort that is hypothesized to make retrieval particularly effective, it is possible that the lack of retrieval effect could explain the absence of a correlation between effort and test performance. I considered that my first study did not fully capture the proposed mechanism I wanted to study, which is that effort while studying impacts performance. The hypothesis in the literature is that retrieval is more effective because it is "effortful". However, in order to evaluate this mechanism, I would first need to see that retrieval is in fact more effective than rereading. Therefore, I may

need to replicate the retrieval effect to determine if there is a correlation between effort and better performance in the retrieval condition. Since this was a possibility, I conducted a second study that allows us to more clearly answer our second research question: whether or not effort correlates to test performance on a final memory test.

Research indicates that while rereading can be a more successful strategy in the short term, the impact of retrieval is particularly potent over longer periods of time (Roediger & Karpicke, 2006b). Since the retrieval effect may not emerge until there is a delay, my correlation in Study I could be limited by the performance metric I used. With this in mind, in Study II, I sought to further clarify the relation between effort and performance. Therefore, participants completed a follow-up multiple-choice memory test one week after the original study. This was done to determine if we would see the retrieval effect, and if there was in fact a correlation between effort during the study phase and performance when the retrieval effect is replicated.

Study II

Given the results of Study I, we wanted to further elucidate the relationship between the three facets of effort and test performance to address our second research question. With this in mind, we made a few methodological changes to our follow-up study. First, since the rereading group performed better in Study I, we aimed to replicate the retrieval effect in Study II to determine how successful retrieval could correlate to our effort measures. We did this by adding a delayed test a week after the initial study, in addition to the immediate test.

While not a main question of interest, I also wondered whether study strategies differentially impact knowledge-based compared to application-based test performance.

For example, it is possible that while rereading was an effective strategy for rote knowledge, using active recall may have a benefit for processing information at a deeper level for questions that require a student to apply their knowledge. Building from this, I also assessed if the three facets of effort correlate to test performance for certain types of questions. As such, the multiple-choice knowledge test in the second study included both knowledge and application questions (sample questions are provided in the Appendix).

Finally, although this was not my main aim, I also aimed to further elucidate whether the results surrounding our subjective experiences of interest are generalizable to different subjects and longer study materials. When undergraduate students study, the content is often complex and study periods when preparing for exams can last hours, so it is of interest to determine if subjective experiences differ between study strategies with longer, more complex stimuli. In addition, Study II was conducted in an in-person lab setting.

Methods

Participants were recruited from a pool of undergraduate students in an introductory psychology class at McMaster University and were compensated with partial course credit. Registration took place over the McMaster SONA database for psychology research. Data were collected from 53 participants with usable data. Delayed test data were collected from 35 participants.

Procedure

All participants were given 15 minutes to read a passage on sleep and sleep disorders (Spielman et al., 2020; see Appendix B). Following the initial reading phase,

participants were randomly assigned to study the content of the passage for 15 minutes in either the retrieval (recall) or rereading condition. In the retrieval condition, participants typed into a text box all of the things that they could remember from the passage before their time elapsed. In the rereading condition, participants were told to reread the passage in order to remember as much information as possible. Immediately following the study phase, participants self-reported their subjective experiences of difficulty, felt effort, fatigue, and flow. All participants then completed a final 32 question multiple choice memory test consisting of 24 knowledge-based questions and 8 application-based questions. Participants also completed a retrospective motivation judgment. During the follow-up session one week later, all participants completed a second multiple choice memory test in the same format as the first. The memory tests were counterbalanced across conditions.

Results- Study II

The results for this study are separated into three sections. The first section will use a series of linear regressions to examine the effects of initial understanding, motivation, and study strategy on subjective experiences (difficulty, felt effort, fatigue, and DEC/flow). The second section will focus on correlations between effort and performance. The third section will focus on effort and performance analyses by question type (knowledge or application). All analyses were completed in R (R Core Team) using the RStudio IDE. The Fisher's r to z transformations were conducted using Quantpsy (Preacher, 2002).

Part I: Subjective Experience

In this section my analyses address whether initial understanding, participant motivation, and study strategy (condition) had a significant impact on participants' subjective experiences during the study phase. I used linear regressions to examine the impact of initial understanding, motivation, and condition on the facets of cognitive effort (task difficulty, felt effort, and fatigue) and DEC. The four linear models for difficulty, felt effort, fatigue, and flow were tested and met the assumptions of a linear regression.

Perceived Difficulty

To examine if perceived difficulty varies by strategy, a linear regression was conducted to analyze the effects of initial understanding, motivation, and study strategy (condition) on participants' subjective ratings of how difficult they found the study phase. The overall regression was statistically significant (R^2 =.29 , F(49,3)= 8.24, p <.001). Understanding was a significant predictor of difficulty (p<.01), suggesting that those who had more difficulty understanding the content of the reading perceived the study phase to be more difficult. Participant motivation was also a significant predictor of difficulty (p<.001). Participants who were more motivated found the study phase less difficult (Table 5, Figure 11). There was no significant difference between conditions (p=.71), indicating that study strategy did not have a significant impact on perceptions of task difficulty.

Table 5. Predictors of Difficulty

Effect	*β*	SE	95% CL		*p*
			LL	UL	
Intercept	3.98	0.61	2.75	5.21	4.0e-8***
Understanding	0.35	0.13	0.09	0.61	0.0099**
Motivation	-0.36	0.10	-0.57	-0.16	0.00065***
Condition:Retrieve	-0.11	0.28	-0.68	0.46	0.71

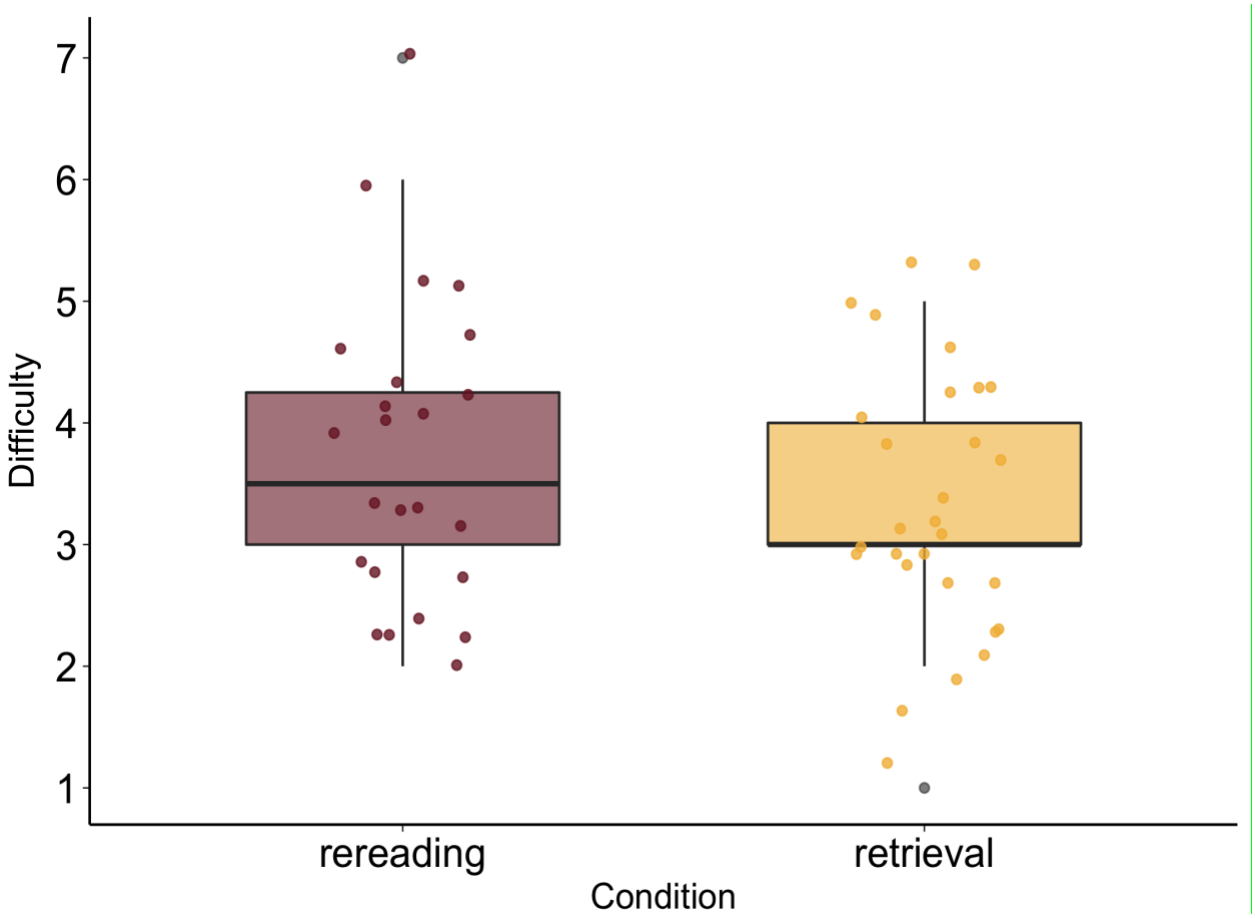

Figure 11. Perceived difficulty by study condition: Rereading (M=3.67, SD=1.34), retrieval (M=3.34, SD=1.08)

Felt Effort

The next regression analyzed the effects of initial understanding, motivation, and condition on participants' ratings of how much effort they feel they put into the study phase. The overall regression was not statistically significant (R^2 =0.08 , F(49,3)= 2.61, p =.06). Understanding was not a significant predictor of effort (p=.50), meaning that participants' initial difficulty in understanding the passage did not influence how much effort they feel as though they put into the study phase. Motivation was a significant predictor of effort (p=.01), such that the more motivated participants were, the more effort they indicated putting into the study phase. Finally, when controlling for understanding and motivation, the condition (or study strategy) that participants used was not a significant predictor of felt effort (p=.54) (Table 6, Figure 12).

Table 6. Predictors of Effort

Effect	*β*	SE	95% CL		*p*
			LL	UL	
Intercept	3.32	0.69	1.94	4.71	1.41e-05***
Understanding	0.10	0.15	-0.20	0.40	0.50
Motivation	0.29	0.11	0.06	0.52	0.013*
Condition:Retrieve	0.19	0.32	-0.44	0.83	0.54

Note: *$p < .05$. **$p < .01$. ***$p < .001$

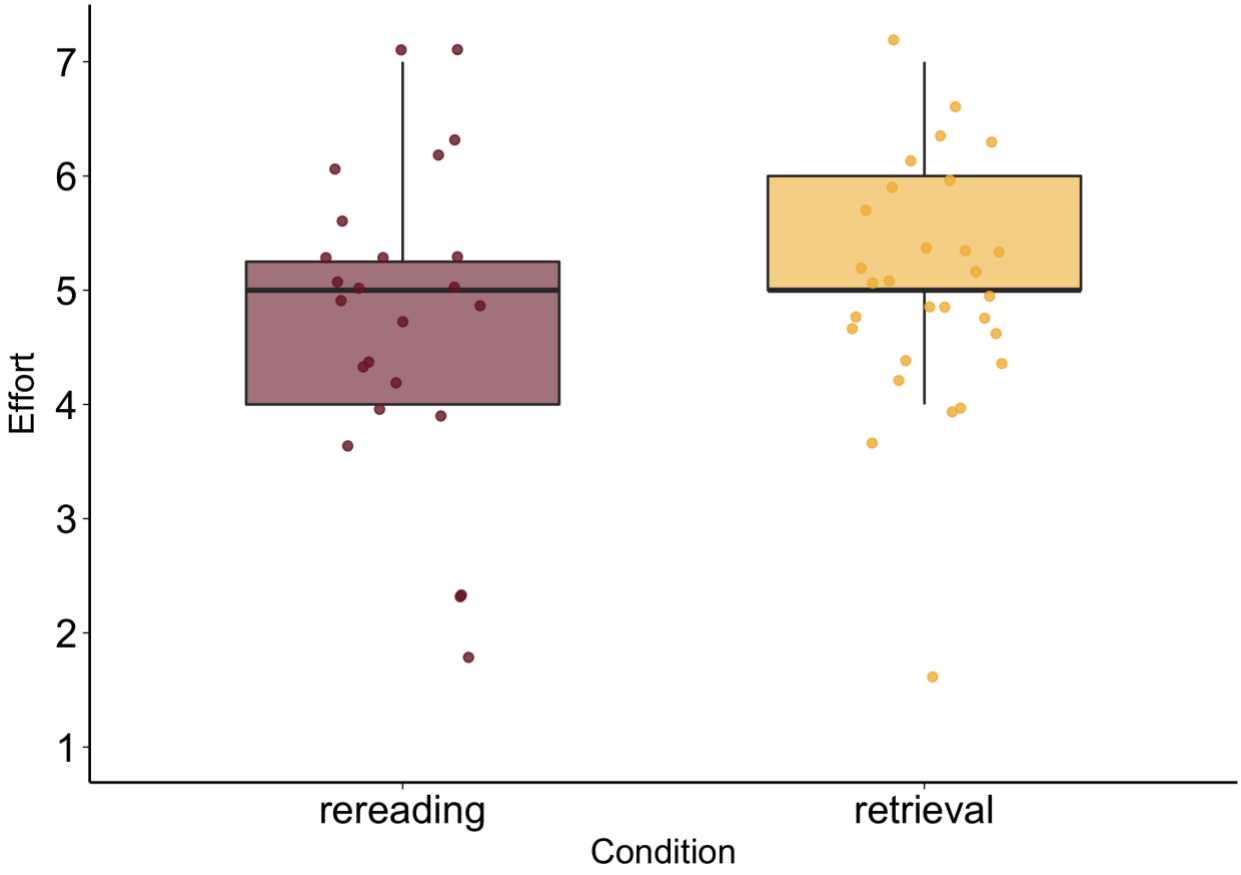

Figure 12. Felt effort by study condition: Rereading (M=4.71 SD=1.37), retrieval (M=5.03, SD=1.08)

Fatigue

Finally, we examined the impact of understanding, motivation, and study strategy on participants' ratings of how fatiguing they found the study phase. The overall regression was statistically significant (R^2 =0.35 , F(49,3)= 10.51, p <.001). Understanding was a significant predictor of fatigue (p<.01). The more difficult participants found it to understand the initial reading, the more fatigued they felt during the study phase. Motivation was also a significant predictor of fatigue (p<0.001). The more motivated a participant was, the less draining they found the study phase. Study

strategy was not a significant predictor of fatigue (p=.68), meaning that neither strategy was significantly more draining (Table 7, Figure 13).

Table 7. Predictors of Fatigue

Effect	β	SE	95% CL		p
			LL	UL	
Intercept	4.37	0.75	2.87	5.88	4.24e-07***
Understanding	0.46	0.16	0.13	0.78	0.0064**
Motivation	-0.52	0.12	-0.77	-0.27	9.62e-05***
Condition:Retrieve	-0.14	0.35	-0.84	0.55	0.68

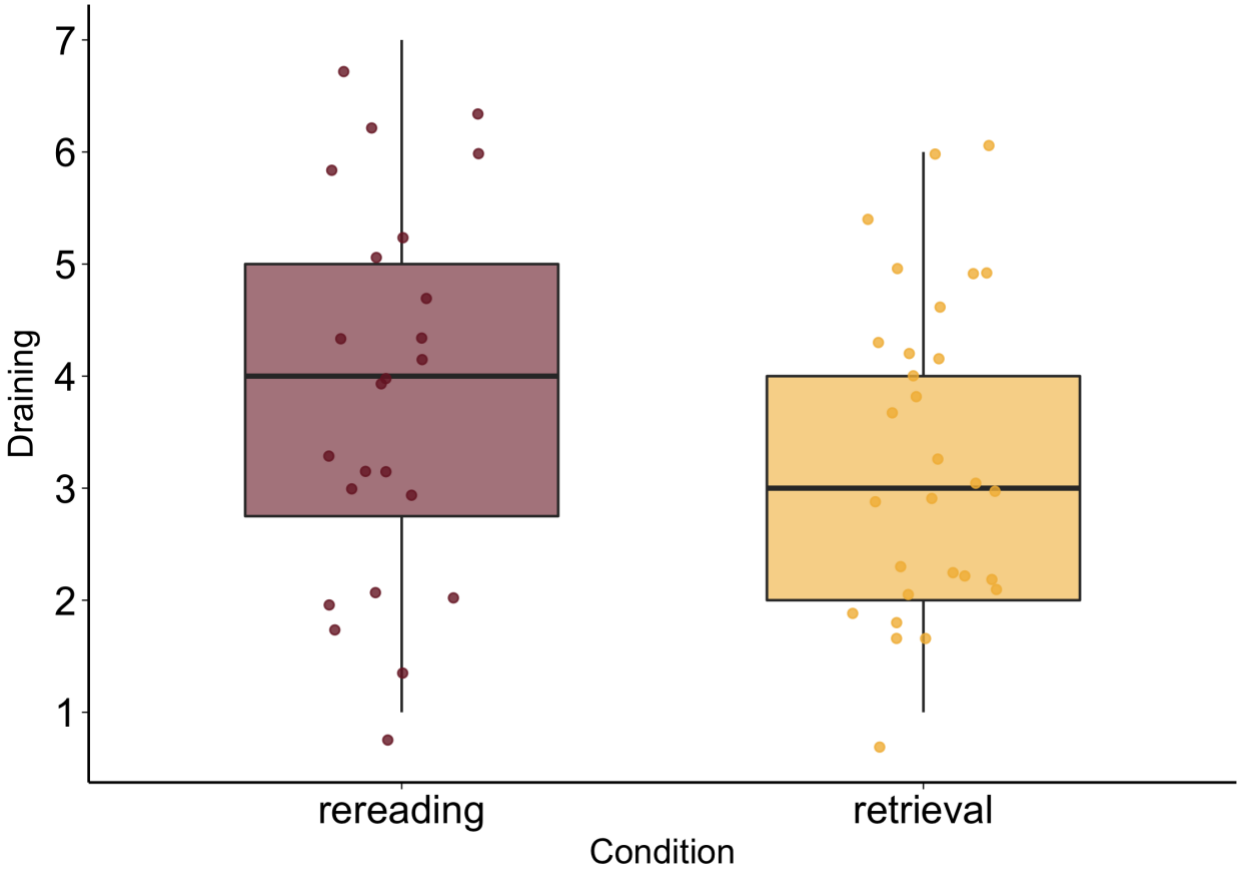

Figure 13. Fatigue by study condition: Rereading (M=3.79 SD=1.69), retrieval (M=3.34, SD=1.40)

Flow

We next examined the impact of initial understanding, motivation, and study strategy on the subjective experience of flow using a linear regression. The overall regression was statistically significant (R^2 =0.12 , F(49,3)= 3.32, p=.03). Understanding was not a significant predictor of flow (p=.76). Motivation was significant, such that participants who were more motivated experienced more flow (p=.03). Flow did not significantly differ between the two strategies (rereading vs. retrieval), p=.09 (Table 8, Figures 14-15).

Table 8. Predictors of Flow

Effect	*β*	SE	95% CL		*p*
			LL	UL	
Intercept	3.09	0.74	1.61	4.56	0.00011***
Understanding	-0.05	0.16	-0.36	0.27	0.76
Motivation	0.26	0.12	0.02	0.51	0.03*
Condition:Retrieve	0.59	0.34	-0.09	1.28	0.09

Note: *$p < .05$. **$p < .01$. ***$p < .001$

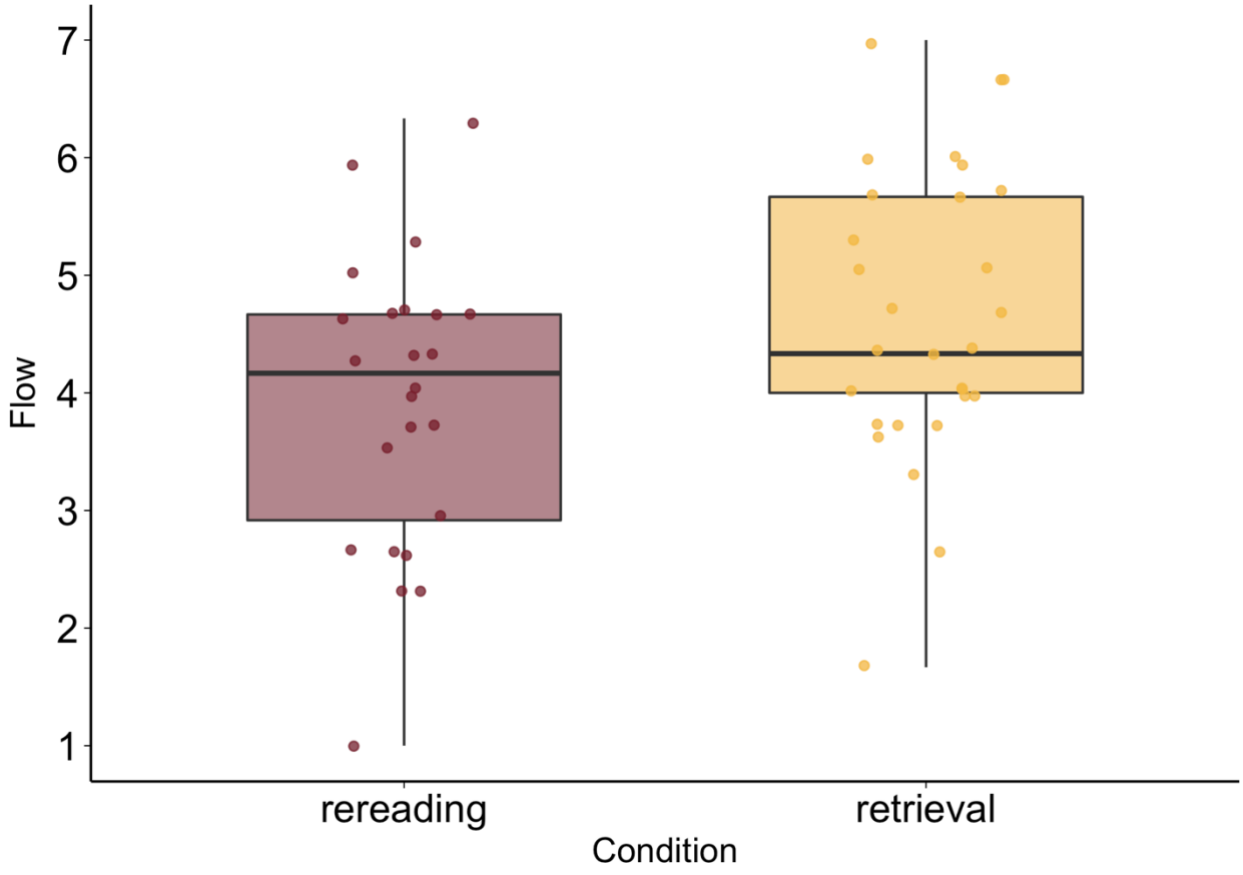

Figure 14. Flow by condition, rereading: M= 3.94, SD=1.25, retrieval: M=4.67, SD=1.25

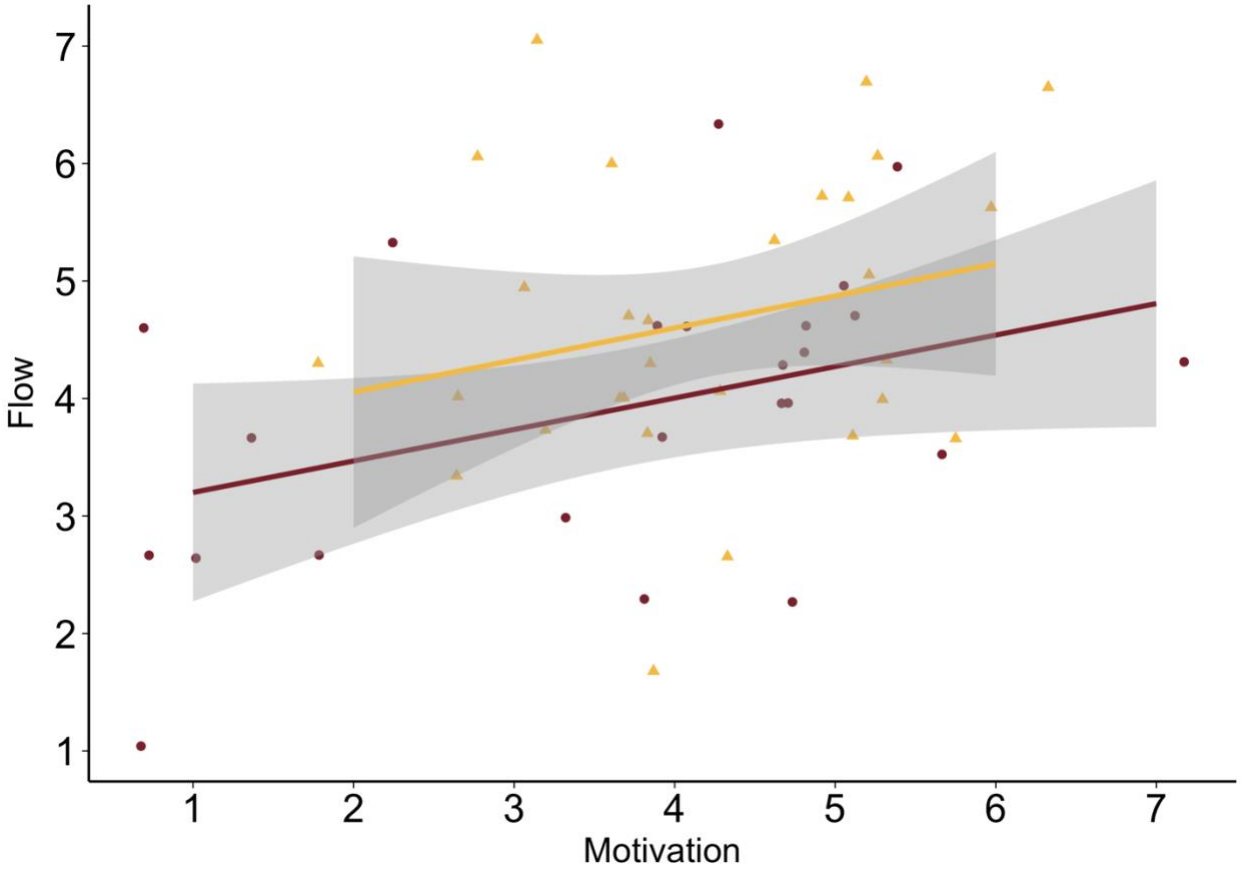

Figure 15. Flow and Motivation

Part II: Correlations Between Cognitive Effort and Performance

This analysis consists of all the final test performance data. I first look at the correlations between the three facets of effort (task difficulty, felt effort, and fatigue) and immediate test performance. Next, I performed effort correlations for the delayed test written one week after the original to clearly address my second research aim. Each of the correlations is separated by strategy, so for each facet of effort, there is one correlation for the rereading condition and one correlation for the retrieval condition.

Note that there is a sample size of n=53 for the immediate test correlations, but due to decreased retention of participants for the follow-up study, the delayed test correlations have a sample size of n=35.

Immediate Test Analyses

A t-test was performed to examine the difference in test scores between the two strategies (rereading and retrieval practice). There was no significant difference between the two strategies, indicating that neither condition performed significantly better on the immediate memory test, rereading (M=17.38, SD=4.52), retrieval (M=15.66, SD=4.73), p=.18 (Figure 16).

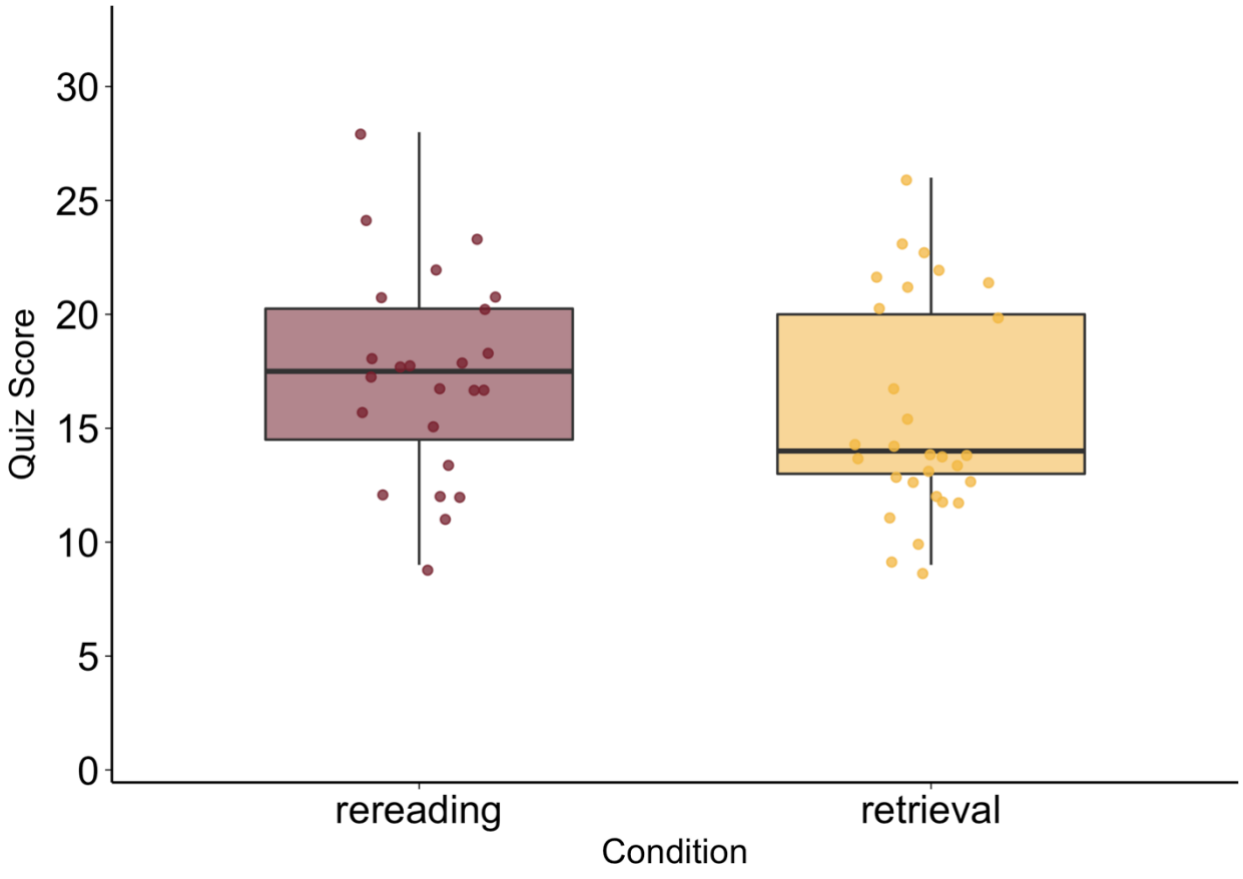

Figure 16. Immediate quiz score by strategy

Perceived Difficulty and Immediate Test Performance

Correlations were conducted to examine the relationship between perceived difficulty during the study phase and immediate test performance. In the rereading condition, there was no significant correlation between difficulty and immediate memory test scores, r(22)=-.11, p=.59. There was also no significant correlation between perceived difficulty and test scores in the retrieval condition, r(27)=-.23, p=.23. To test whether the correlations differed across the two groups I used a Fisher's r to z transformation (Preacher, 2002). The magnitude of the correlation was not significantly different across the groups (Z = 0.42, p = .67) Regardless of condition, there was no significant relationship between how difficult participants found the study phase and how well they performed on the immediate memory test (Figure 17).

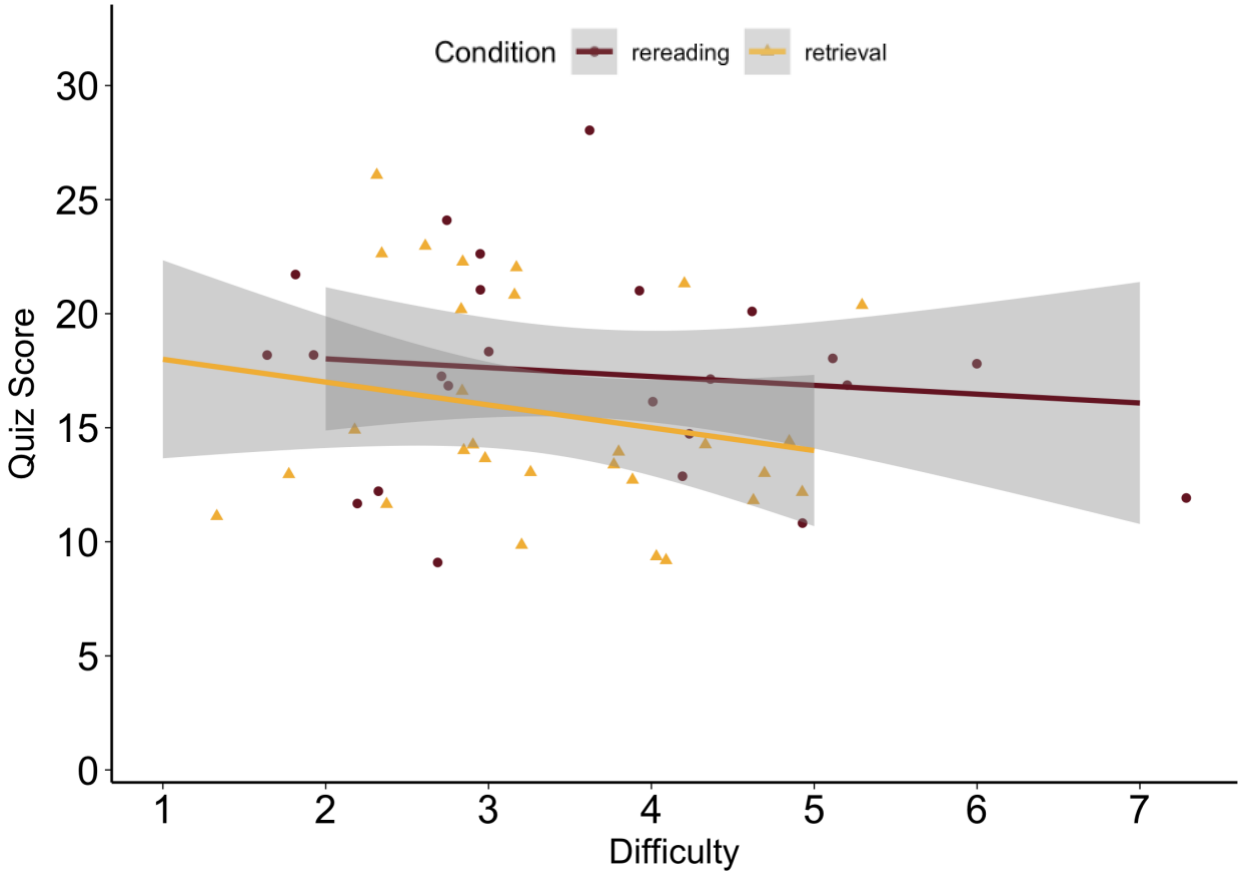

Figure 17. Relationship between perceived difficulty and immediate quiz score

Felt Effort and Immediate Test Performance

Correlations were conducted to analyze the relationship between felt effort during the study phase and immediate test performance with each strategy. In the rereading condition, there was no significant correlation between how much effort participants felt they put into the study phase and test performance, r(22)=.18, p=.40. There was a significant relationship between felt effort and test scores in the retrieval condition, r(27)=.44, p=0.02. The magnitude of the Fisher's r to z transformation correlation was not significantly different across the groups (Z = -.99, p = .32). This would suggest that

there is a weak correlation between felt effort and immediate test performance in the retrieval group (Figure 18).

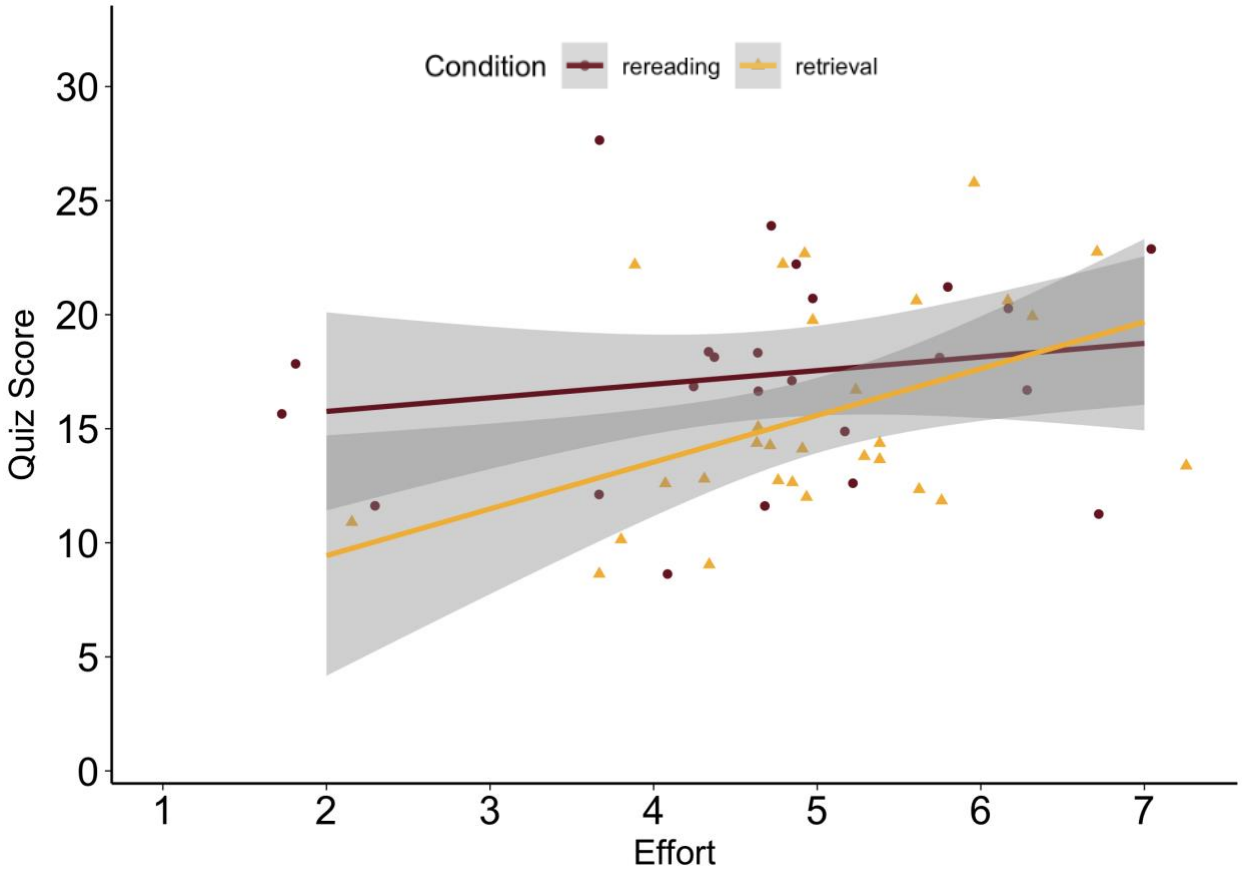

Figure 18. Relationship between felt effort and immediate quiz score

Fatigue and Immediate Test Performance

Finally, correlations were conducted to analyze the relationship between fatigue and test performance. In the rereading condition, there was no significant correlation between fatigue and test score, r(22)=-.20, p=.35. There was also no significant correlation between fatigue and test performance in the retrieval condition, r(27)=-.34, p=.07. To test whether the correlations differed across the two groups I used a Fisher's r

to z transformation (Preacher, 2002). The magnitude of the correlation was not significantly different across the groups (Z = .52, p = .61). This indicates that regardless of study strategy, there was no relationship between how drained participants felt during the study phase and how well they performed on the immediate multiple-choice test (Figure 19).

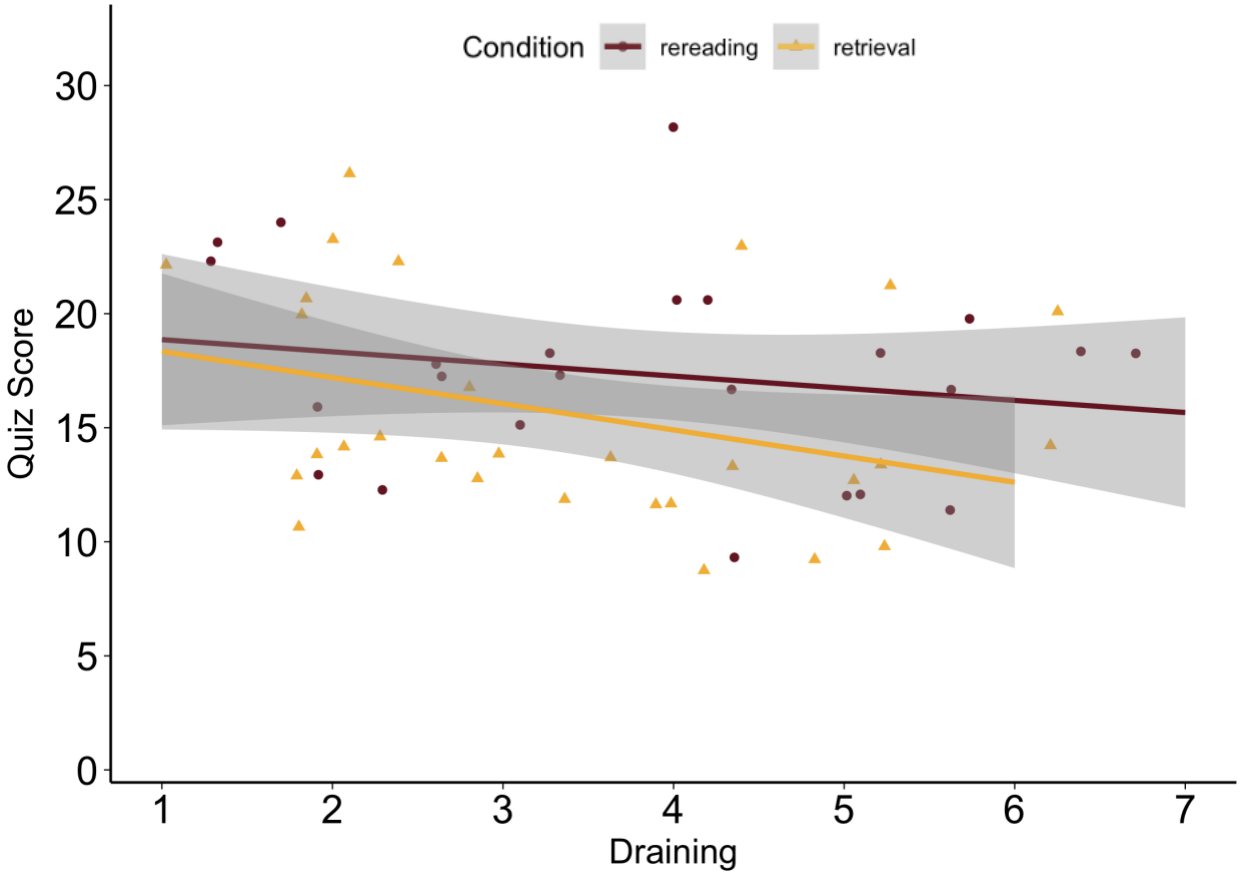

Figure 19. Relationship between fatigue and immediate quiz score

Delayed Test Analyses

A t-test was performed to compare test scores between the two strategies (rereading and retrieval practice). There was no significant difference in test scores

between the two strategies. The retrieval group (M=15.44, SD=4.62) did not perform significantly better than the rereading group (M=15.82, SD=5.84), p=.83, indicating that the retrieval effect was not replicated (Figure 20).

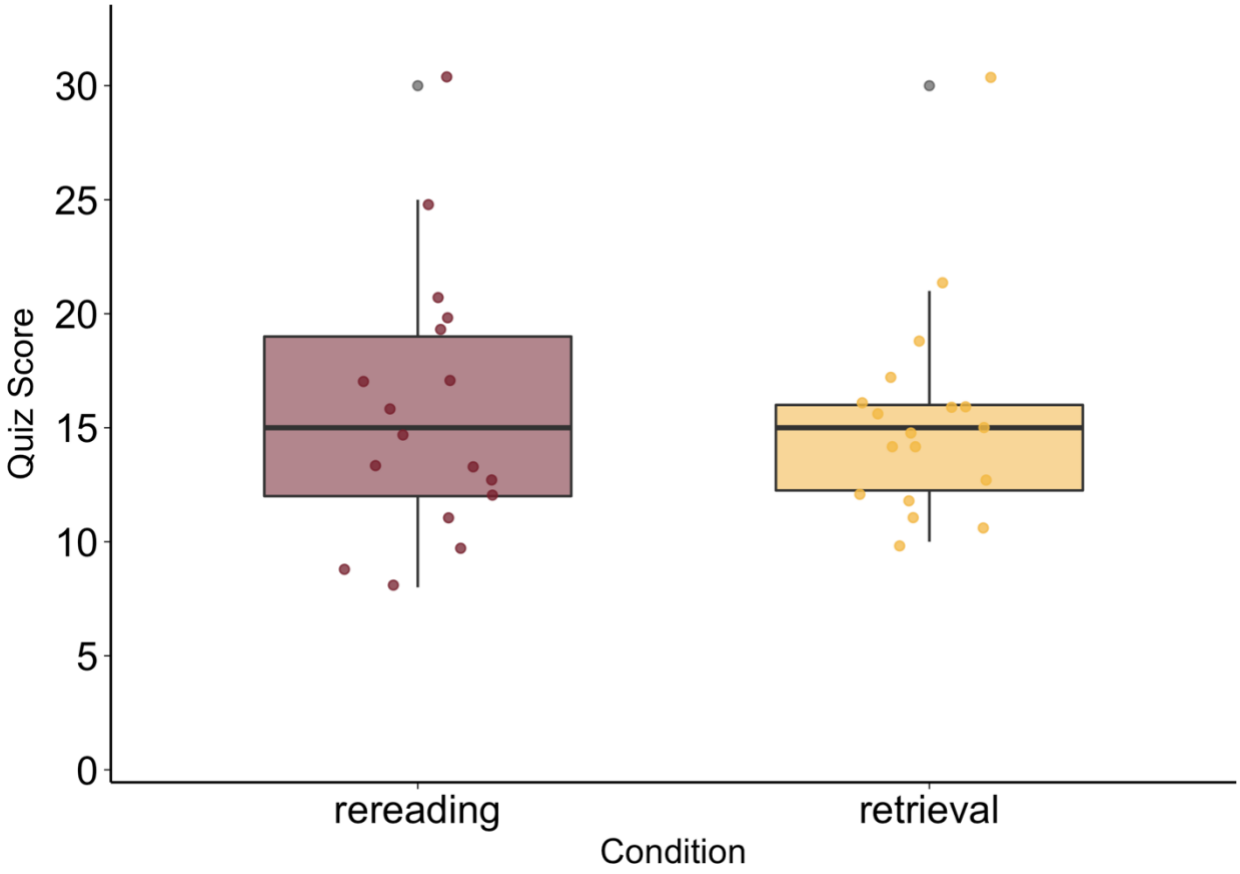

Figure 20. Delayed quiz score by strategy

Perceived Difficulty and Delayed Test Scores

Next, we examined the relationship between perceived difficulty during the study phase and performance on the delayed test written one week after the original study session. In the reading condition, there was no significant correlation between perceived

difficulty and test scores, r(15)=-.08, p=.77. Similarly, there was no significant correlation between perceived difficulty and test scores in the retrieval condition, r(16)=-.34, p=0.16. To test whether the correlations differed across the two groups I used a Fisher's r to z transformation (Preacher, 2002). The magnitude of the correlation was not significantly different across the groups (Z = 0.74, p = .46). Regardless, of strategy, participants' perceived difficulty did not correlate to delayed test scores (Figure 21).

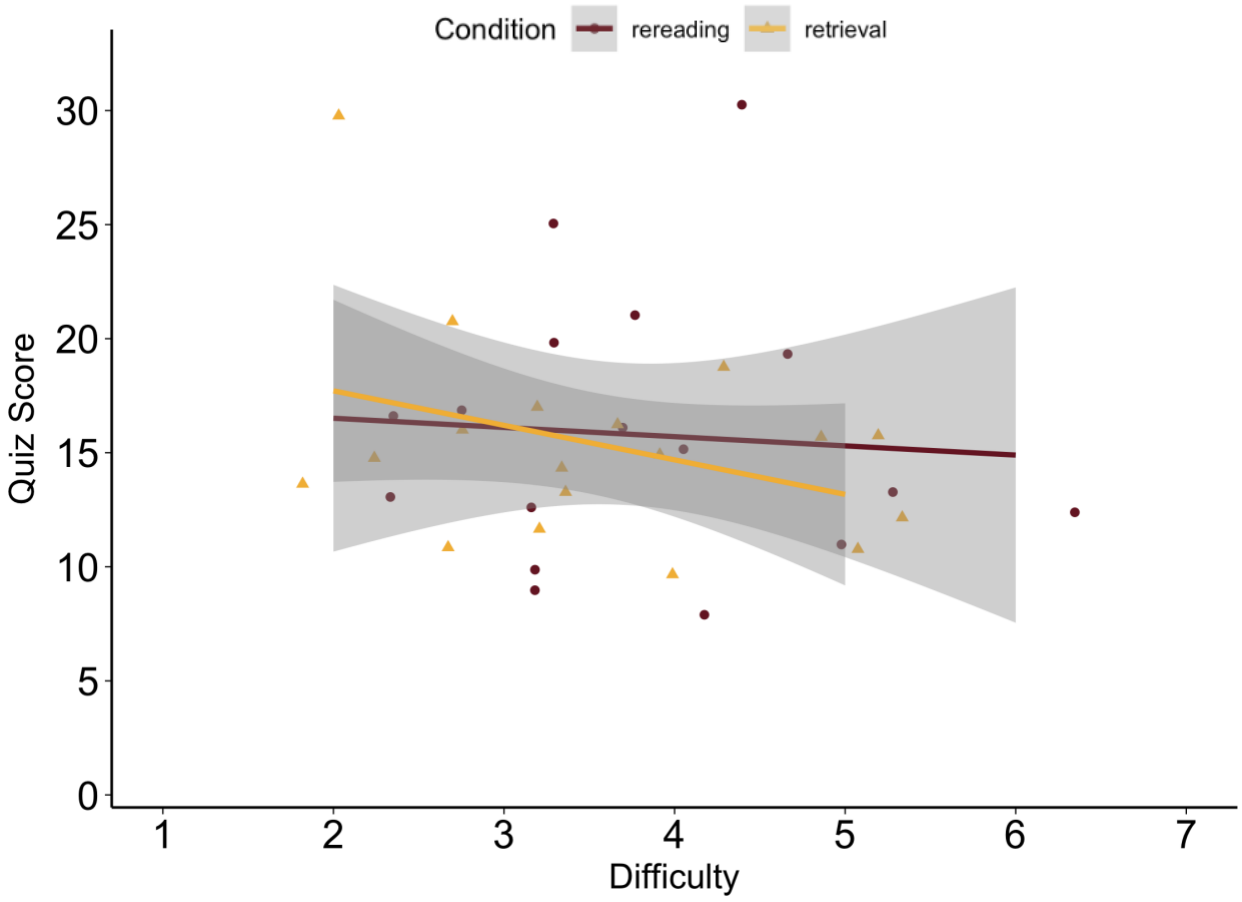

Figure 21. Relationship between perceived difficulty and delayed quiz score

Felt Effort and Delayed Test Scores

Next, correlations were conducted to examine the relationship between how much effort participants felt as though they put into the study phase and scores on the delayed test. There was no significant relationship between felt effort and test performance in the rereading condition, r(15)=.08, p=.76, or the retrieval condition, r(16)=-.40, p=.10 (Figure 22). A Fisher's r to z transformation (Preacher, 2002) indicated that the magnitude of the correlation was not significantly different across the groups (Z = 1.36, p = .17). This indicates that regardless of condition, felt effort was not correlated with performance on the delayed test.

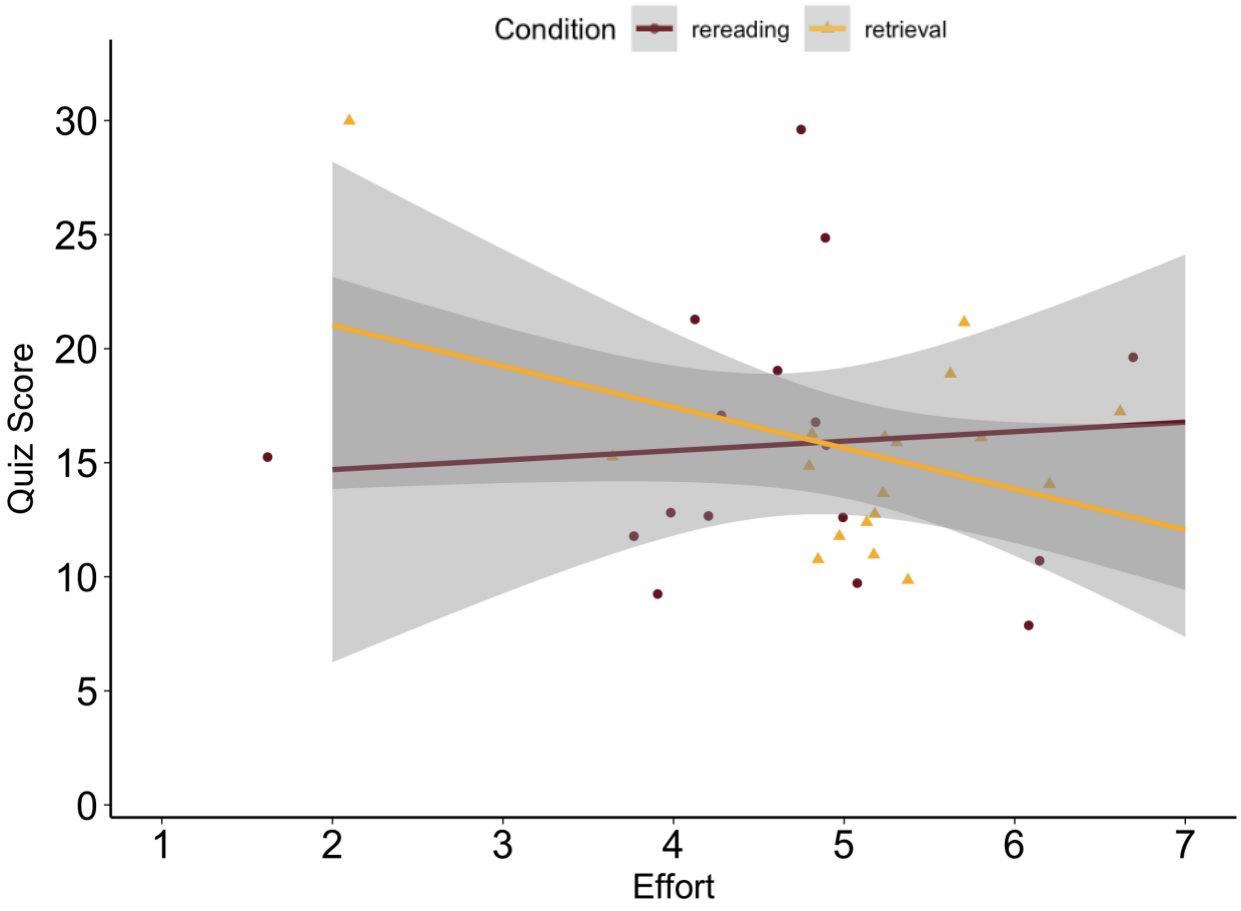

Figure 22. Relationship between felt effort and delayed quiz score

Fatigue and Delayed Test Scores

Finally, the relationship between how draining participants found the study phase and delayed test performance was analyzed. In the rereading condition, there was no significant correlation between fatigue and test scores, r(15)=-.32, p=.22. Similarly, there was no significant correlation between fatigue and test performance in the retrieval condition, r(16)=-.11, p=.66. A Fisher's r to z transformation (Preacher, 2002) indicated that the magnitude of the correlation was not significantly different across the groups (Z = -.60, p = .55). This indicates that regardless of condition, participants' fatigue did not correlate with performance on a delayed test (Figure 23).

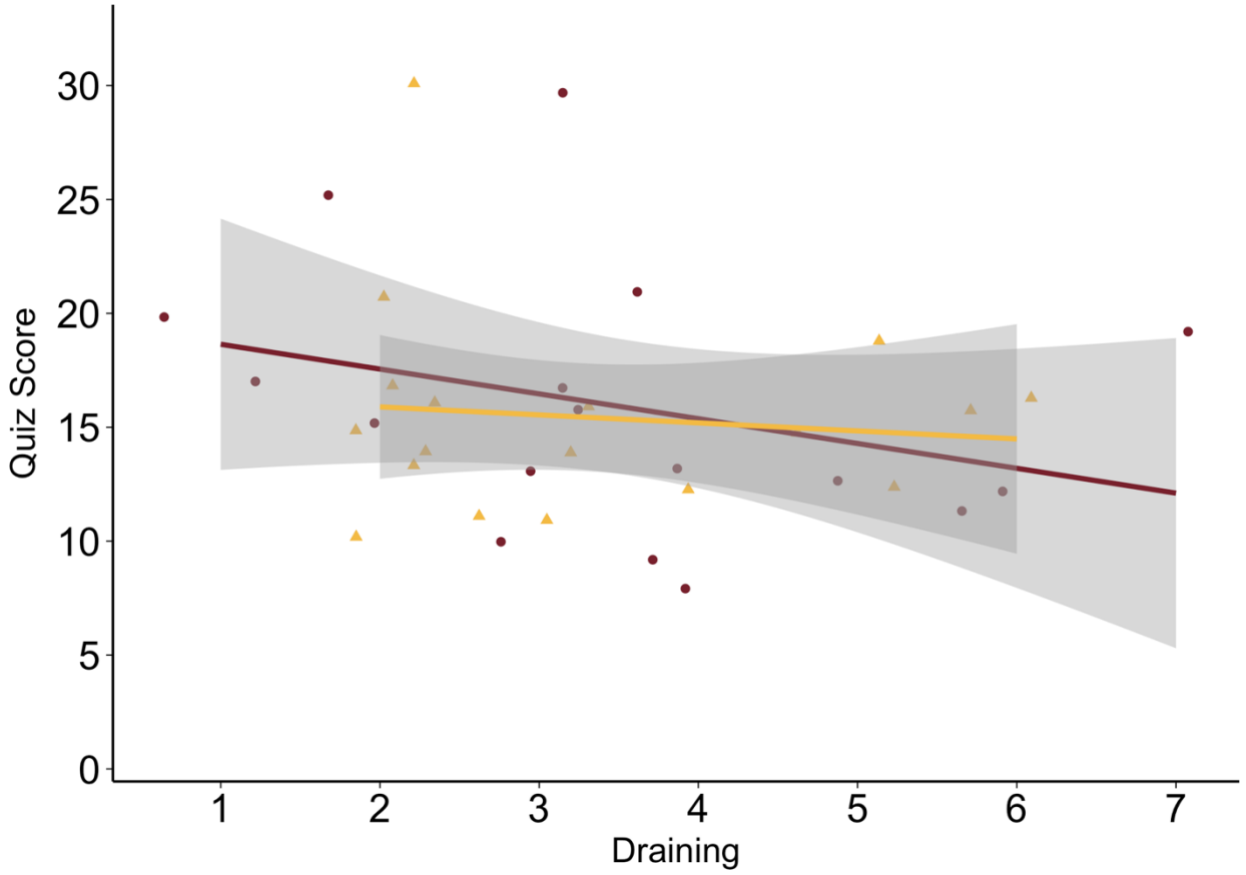

Figure 23. Relationship between fatigue and delayed quiz score

Part III: Correlations for Question Type

For the third section, I looked at the relationship between the two study strategies (rereading and retrieval) and performance on different types of test questions (knowledge or application questions). Finally, I also examined the relationships between the three facets of effort and test performance by question type.

Immediate Test Performance

A t-test was conducted to analyze the difference in test scores for knowledge-based questions in the rereading and retrieval conditions. There was no significant difference between the two strategies, rereading (M=12.83, SD=3.38), retrieval (M=11.79, SD=3.74), p=.29, suggesting that study strategy did not significantly impact performance on knowledge-based questions (Figure 24).

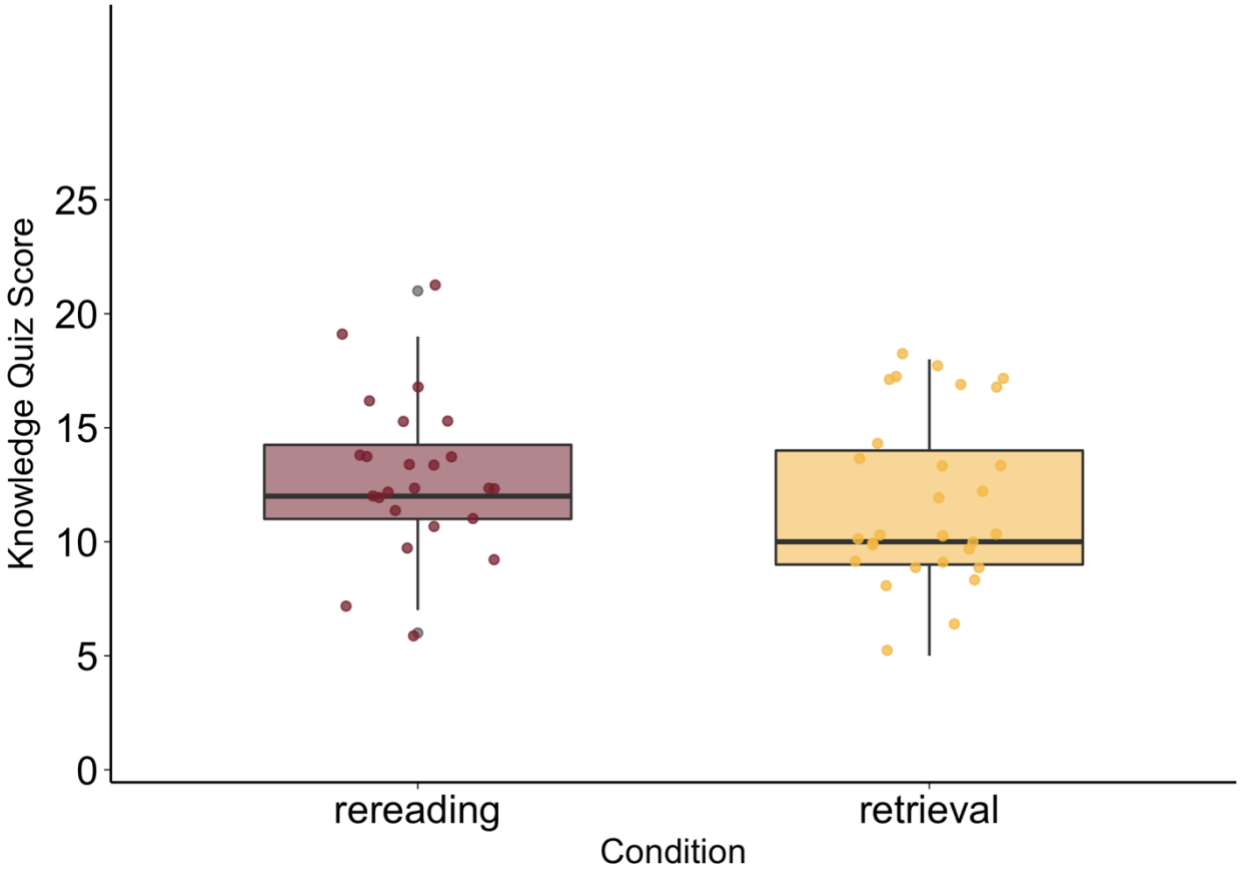

Figure 24. Immediate quiz score for knowledge-based questions by condition

Application Questions- Immediate Test

A t-test was conducted to analyze the difference in test scores for application-based questions by strategy (rereading or retrieval). There was no significant difference between the two strategies, reading (M=4.54, SD=1.79), retrieval (M=3.86, SD=1.81), p=.18, suggesting that study strategy did not significantly influence performance on application-based questions on an immediate memory test (Figure 25).

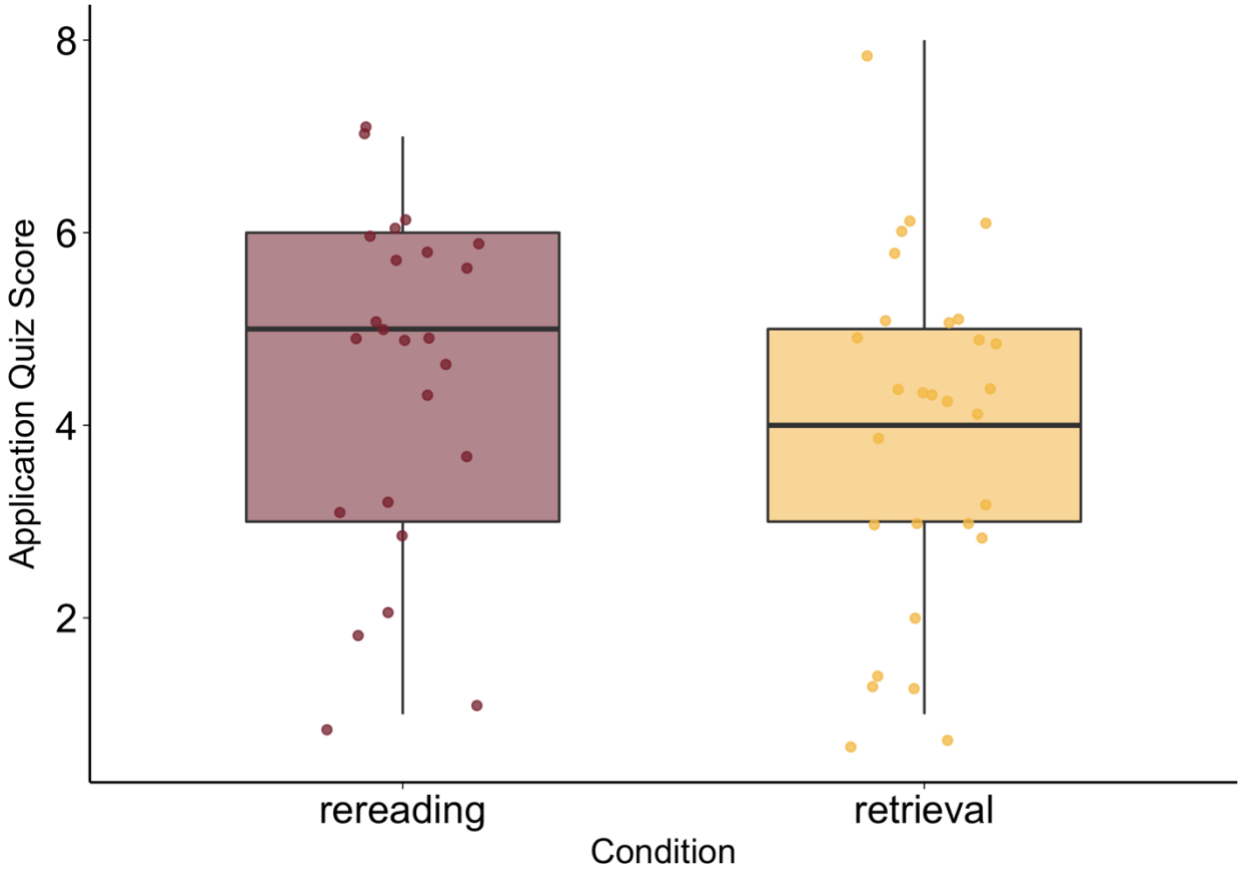

Figure 25. Immediate quiz score for application-based questions by condition

Delayed Test Analyses

A t-test was conducted to analyze for a difference in delayed test scores for knowledge-based questions between the two study strategies (rereading and retrieval). Neither group (rereading, M=11.65, SD=4.31, or retrieval, M=11.17, SD=3.19, p=.71), performed better on the knowledge-based questions of the delayed test (Figure 26).

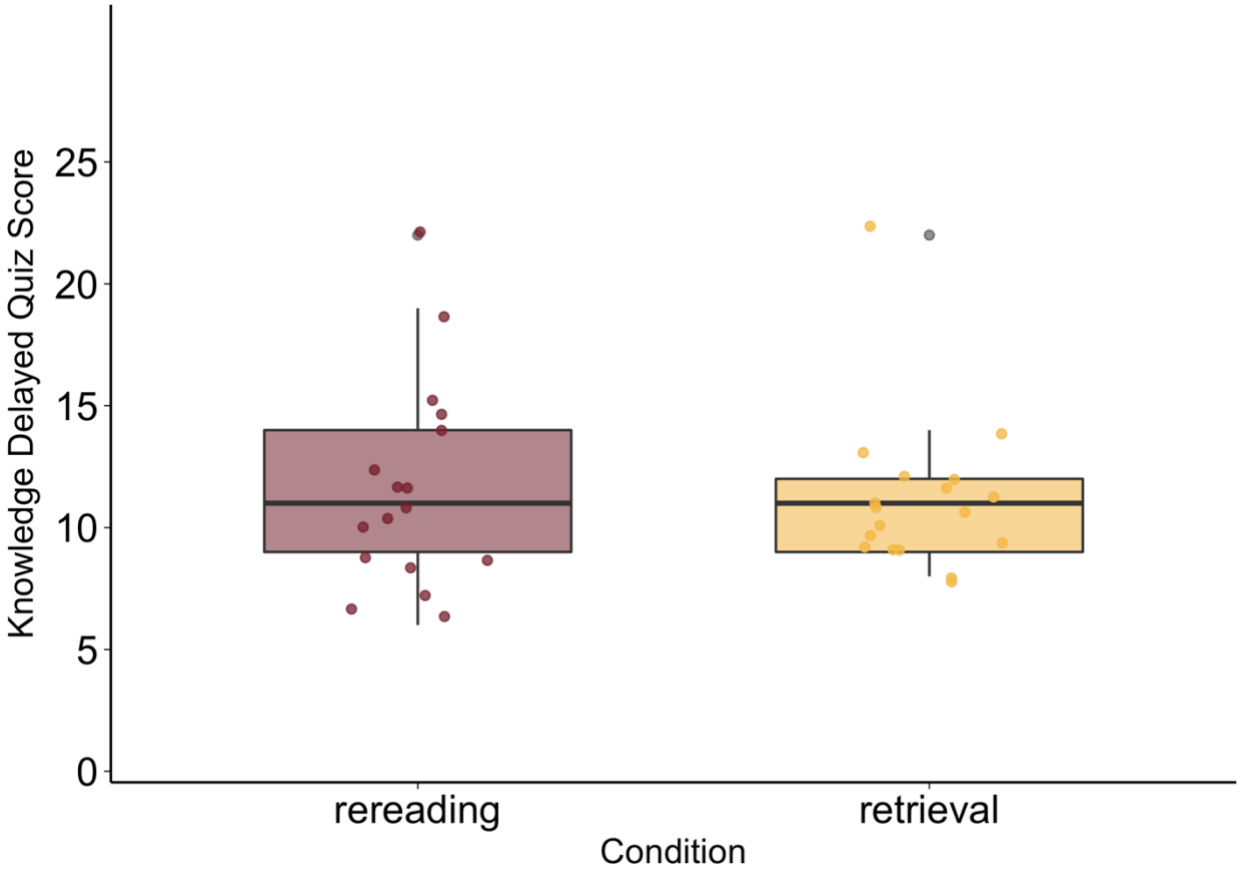

Figure 26. Delayed quiz score for knowledge-based questions by condition

Finally, a t-test was conducted to analyze for a difference in delayed test scores for application-based questions between the two study strategies (rereading and retrieval). Neither group (rereading, M=4.18, SD=2.01, or retrieval, M=4.28, SD=1.71, p=.87), performed better on the application questions of the delayed test (Figure 27).

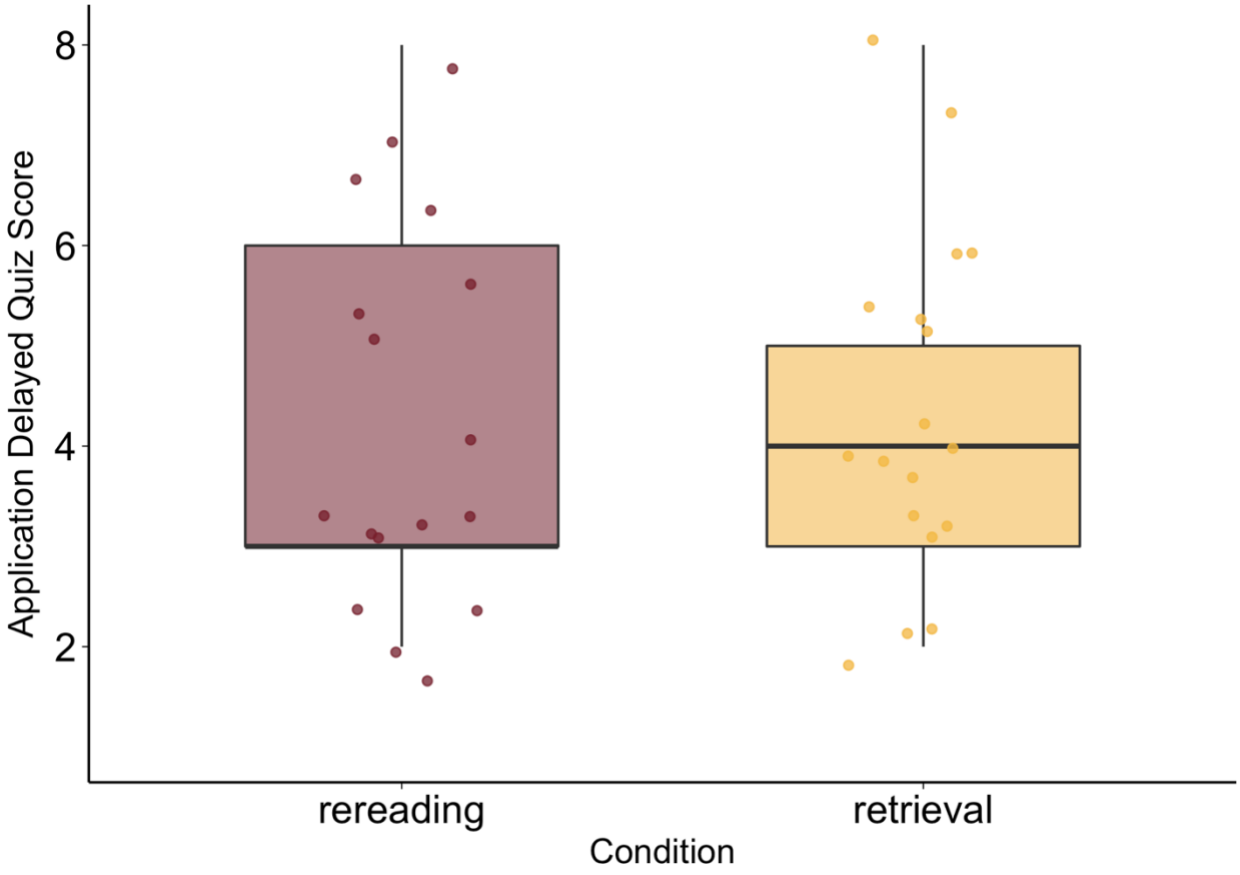

Figure 27. Delayed quiz score for application-based questions by condition

Finally, to determine if there are any correlations between the three facets of effort (task difficulty, felt effort, and fatigue) and performance on application or knowledge-based multiple-choice questions, we conducted a series of correlation analyses. The tests were separated into knowledge or application-based questions, and further divided by immediate or delayed test times. Table 9 contains the correlation values for the rereading condition. There were no significant correlations between task difficulty and performance on knowledge or application questions for either the immediate or delayed tests. There were also no significant correlations between felt effort and performance on knowledge or application-based questions for either the

immediate or delayed tests. Finally, for the rereading group, there were no significant correlations between fatigue and performance for either the immediate or delayed test. Table 10 shows the same correlation values but for the retrieval group. There were no significant correlations between difficulty and performance for either question type, for either the immediate or delayed tests. There was a significant positive correlation between felt effort and performance on immediate knowledge questions (p=.04). There was no significant correlation between felt effort and performance on delayed knowledge questions. There was a significant positive correlation between felt effort and performance on immediate application questions (p=.04), but there was no significant correlation between felt effort and performance on delayed application questions. Finally, there were no significant correlations between fatigue and performance on any of the question types for either the immediate or delayed tests.

Table 9. Correlations between facets of effort and test performance in the rereading group

	Immediate Knowledge	**Delayed Knowledge**	**Immediate Application**	**Delayed Application**
Difficulty	-0.14	-0.05	-0.03	-0.12
Felt Effort	0.11	0.09	0.24	0.02
Fatigue	-0.33	-0.42	0.11	-0.01

Note: *$p < .05$. **$p < .01$. ***$p < .001$

Table 10. Correlations between facets of effort and test performance in the retrieval group

	Immediate Knowledge	Delayed Knowledge	Immediate Application	Delayed Application
Difficulty	-0.2	-0.38	-0.18	-0.21
Felt Effort	0.38*	-0.46	0.37*	-0.22
Fatigue	-0.36	-0.15	-0.15	-0.03

Note: *$p < .05$. **$p < .01$. ***$p < .001$

Study II Discussion

Study II addressed the same goals of the first research study, and further examined my second research aim, which was to determine the relationship between effort and performance. I first aimed to assess whether changing the study strategy that participants used (rereading or retrieval) led to subjective changes in student experiences of effort (as assessed with the facets of task difficulty, effort, and fatigue), and flow. I then aimed to assess how the facets of effort related to both immediate and delayed test performance. Critically, Study II differed from Study I as it included the delayed test written one week after the original, as I believed the correlation between effort and performance could have been limited by the retrieval performance metric (immediate test) I used in Study I. Finally, I investigated whether test performance differed by strategy when considering question type (knowledge or application-based questions), and how the three facets of effort correlate with question type.

To address my first research question, I conducted linear regressions to examine the impact of study strategy on my experiences of interest (task difficulty, felt effort, fatigue, and flow). The linear regressions indicated that there were no significant

differences for any of the facets of effort, suggesting that neither strategy (rereading or retrieval) was perceived as more difficult, participants did not feel as though they exerted more effort in either strategy, and neither strategy was more fatiguing than the other.

Once again, motivation was a significant predictor in difficulty, felt effort, fatigue, and flow. The more motivated a participant was, the more effort they put into the study phase, and the less difficult and fatiguing they found the study phase.

To examine the impact of effort on test performance, I first analyzed the data from the test written immediately following the study phase, further separated by study condition (rereading or retrieval). Perceived difficulty did not correlate significantly with immediate test performance in either condition. When examining felt effort, there was no significant correlation in the rereading condition, but there was a significant positive correlation in the retrieval condition. This result indicates that in the retrieval condition, the more effort that participants felt they put into studying, the better they performed on the immediate memory test. Finally, there were no significant correlations between fatigue and immediate test performance in either condition. These findings could be attributed to a small sample size.

To further examine the impact of effort on test performance, I also analyzed the data from the test written with a one-week delay, again separated by study strategy. This was the measure that aimed to answer my second research goal more clearly.

There was no significant correlation between task difficulty and performance on the delayed test for either condition. There was also no significant correlation between felt effort and performance on the delayed test for either rereading or retrieval. Similarly,

there were no significant correlations between fatigue and test performance on the delayed test in either strategy. Overall, there were no significant correlations between any of the facets of effort and delayed test performance.

Finally, I aimed to determine if there were any differences between strategies for test performance by question type. There were no significant differences in performance between rereading and retrieval for either knowledge or application questions. I then examined the correlations between the different facets of effort and test performance by question type (knowledge or application). Looking at the rereading condition specifically, there was no correlation between perceived task difficulty and performance for either knowledge or application questions on the immediate or delayed test. Further, there was no significant correlation between felt effort and performance on knowledge or application questions for either the immediate or delayed test. Finally, there was no significant correlation between fatigue and performance by question type for either the immediate or delayed test. When looking at test performance by question type for the retrieval condition, a few patterns emerged. There were no significant correlations between task difficulty and performance by question type on either the immediate or delayed tests. For felt effort, there were significant positive correlations between effort and performance on both knowledge and application questions on the immediate test, but no significant effects for either question type on the delayed tests. Finally, there were no significant correlations between fatigue and test performance by question type for either the immediate or delayed test. This would suggest that study strategy does not appear to affect performance by question type, and that task difficulty and fatigue do not correlate to performance on certain question types. Increased feelings of felt effort

may relate to better performance on both knowledge and application questions when students retrieve. However, due to the small number of participants, it is difficult to draw conclusions, so it would be of interest to run these correlations again with a larger sample size.

General Discussion

In this series of two studies, I had two main goals. The first was to determine whether participants' subjective experience systematically differed by study strategy. In Study I, I found a significant difference between strategies in terms of task difficulty, such that the retrieval condition had significantly higher self-reported scores than in the rereading condition. However, there were no differences between the strategies for felt effort or fatigue. In Study II, there were no significant differences in any of the three facets of cognitive effort by strategy, although this could be attributed to low sample size. Both studies found no significant differences in flow between rereading and retrieval, which would suggest that students are not misled by the passivity, or the perceived "effortlessness" of rereading.

One key contribution of my study to the literature on effort in student studying is that I more precisely defined how I was evaluating cognitive effort by teasing it apart into distinct facets, instead of asking one question about effort as a whole. This allowed me to understand how strategy specifically impacts each facet of task difficulty, felt effort, and fatigue. In Study I, there was a significant difference in task difficulty between the two strategies. This might suggest that "effort" in retrieval is related to the facet of task difficulty specifically. Some of the wording in the literature does lend itself to the claim that retrieval effort might be referring more specifically to difficulty. For example, Pyc &

Rawson (2009) write that it is the “greater difficulty” in retrieval that enhances memory for content on a final test. It is possible that retrieval is more difficult than rereading, which makes it successful, but despite the demands of the task, students do not subjectively feel as though they put in more effort. However, if this were the case, we might also expect to see a positive correlation between difficulty and test performance, which was not the case here. Nonetheless, this is an explanation that could merit further consideration.

My second research question aimed to better understand the relationship between the three facets of cognitive effort (task difficulty, felt effort, and fatigue) and academic performance on a final multiple-choice test. In Study I, there was a significant negative correlation between how difficult participants found the study phase and test performance, and also a significant negative correlation between fatigue and test score. There was no relationship between felt effort and test performance in either the rereading or the retrieval condition.

Critically, the design of Study II aimed to more clearly assess my second research question, which examined the correlation between effort and performance by strategy. One of my main questions of interest after Study I was if the reason why we did not see a significant difference in effort between the two strategies is because we did not see the testing effect, where using retrieval benefits test performance. Since the benefit of retrieval may not emerge until delayed testing is conducted, the effort-performance correlation is limited by the performance metric used in the first study. It is possible that Study I may not have captured the mechanism that I wanted to study- whether the subjective experience of effort during studying could explain performance in

the retrieval condition. As such, I added a delayed test with the goal of further examining how student experiences of effort relate to test performance. However, it is important to note that the testing or retrieval effect was not replicated in Study II, possibly due to a small sample size of 35 participants.

With regards to difficulty and test performance, recall that there was a significant negative correlation between difficulty and performance for both conditions in Study I. There were no significant correlations between difficulty and performance in Study II for either the immediate or delayed memory tests, although the correlations were in the same direction as Study I. The differing results in Study II are possibly due to small sample size in the second iteration of the study.

In terms of felt effort, there was no significant correlation for either strategy between effort and performance in Study I. However, there was a positive correlation for felt effort and immediate test performance specific to the retrieval condition in Study II. There are a few potential reasons for the mixed felt effort findings between the two studies. First, it is possible that while students are putting high levels of effort into studying, they are not directing their time and attention appropriately. For example, it is possible that some students may have put plenty of effort into rereading or recalling the first few concepts presented in the passage, but neglected to study other information later in the passage. Or, participants could have devoted their attention to reviewing the content that they found most interesting or struggled the most with, and therefore failed to restudy all of the information, impacting test performance. Another related possibility is that participant effort could vary based on what the participant is studying and throughout the study period. Wise and Kong (2005) suggest that the amount of effort

that participants put into a test can fluctuate throughout the length of test. It is possible that the same effect is seen throughout a study period, so this could provide justification for an experience sampling study or conducting a future study that probes felt effort throughout the study phase to look at the effort participants feel as though they expended periodically, instead of one measure of effort.

There were also some mixed findings with regards to fatigue, with a significant negative correlation between fatigue and test performance for both strategies in the first study. There was no significant correlation between fatigue and test performance on either the immediate or delayed tests in Study II, although the correlations were once again in the negative direction. While the insignificant findings in Study II could be related to a small sample size, there is reason to believe that those who are more fatigued perform worse on a quiz, as seen in Study I. There is prior evidence that fatigue has a negative impact on academic performance. For example, one study found that when children write standardized tests later in the day, once cognitive resources are depleted, scores on these tests decrease (Sievertsen et al., 2016). In the same way, it is possible that the fatigue a student feels after studying would negatively impact their test scores. Further analyses could look at baseline levels of fatigue or the time of day at which a participant completed the study in order to determine if this is the case.

Taken together in this set of studies, I have evaluated whether changing strategy leads to systematic changes in student experience, and how effort correlates to performance. However, when discussing my results surrounding cognitive effort, it is important to recall that the literature to date does not precisely define what is meant by effort. For example, when researchers address the notion of “effort”, it is unclear

whether this effort is measured by student experience, by physiological measures, or by another construct entirely. For the purpose of this study, we first tested whether effort could be a subjective experience, since I proposed that it could be a students' subjective experience while studying that could be leading to certain choices about their studying, such as which strategy to use. It is important to note that there are other ways in which subjective experience can be measured. In addition to Shepherd (2022) raising the point that effort is unclear, Dunn et al. (2019) also acknowledge that what specifically is meant by effort is still an open question. There are other ways in which effort has been conceptualized and measured in the literature, beyond the probes we used (Hsu et al., 2017). With regards to studying specifically, Kelly & Risko (2022) use the amount of a time a participant studies a certain item as a measure of how much effort was put towards remembering that stimulus. Some literature also defines effort as something akin to a physical resource that participants choose to exert in a task (Ackerman & Thompson, 2017, Kahneman, 1973), while other researchers view cognitive effort in terms of a cost-benefit analysis where humans balance the costs and benefits of a certain task with another conflicting task that they could choose instead (Kurzban et al., 2013). Since there are many accounts of what is meant by effort, and there is no consensus among researchers about how to best measure it, it is possible that there is another way to measure subjective effort that could lend itself to the retrieval-effort claims in the literature.

It is important to note however that there are also other ways to measure effort, beyond the evaluation of subjective experiences. One popular method to measure cognitive effort is through physiological measures, such as skin conductance (Botvinick

& Rosen, 2009) or pupil diameter (Krejtz et al., 2020; Piquado et al., 2010). When referring to the idea that retrieval is effortful, it is possible that the literature refers to a specific set of physiological measures. It would be interesting to see if there are differences in a physiological response, such as increased pupil dilation, between study strategies as a marker of cognitive effort while studying. However, this continues to highlight the lack of specificity surrounding a definition of effort in the literature (Ackerman & Thompson, 2017; Dunn et al., 2019; Kahneman, 1973; Kurzban et al., 2013).

Finally, while not a main research question, motivation emerged as a critical factor in our findings. In Study I, motivation was not a significant predictor of difficulty in the model, but there was a significant negative relationship between difficulty and motivation in Study II, such that participants who were more motivated found the study phase less difficult. In both studies, motivation was significant in the regression model for felt effort, such that those who were more motivated felt as though they put more effort into the study phase. For fatigue, motivation was a significant predictor in both models, such that those who were more motivated were less fatigued. Finally, those who were more motivated also experienced more DEC during the study phase.

The motivation findings in Study I provide an indication that participants are in fact able to discriminate between different facets of effort. While motivation did impact how much effort participants put into studying, and how much the task fatigued them, it did not impact their perception of task difficulty. This would suggest that while motivation can impact some facets of effort, it may not impact all facets, such as the perception of how challenging a task is. This could be because motivation impacts how hard

someone tries (i.e., how much effort they want to put in) but does not impact their assessment of the inherent difficulty of the task- which the present results suggest might remain stable regardless of the level of motivation. This idea supports the use of an effort measure that disentangles the three facets of cognitive effort and shows that these are distinct measures that participants can distinguish between when probed.

In sum, our findings suggest that motivation is a factor that strongly influences student experiences while studying. The literature has found that students who are less motivated also typically spend less time studying for assessments (Koudela-Hamila, 2019). If students who are more motivated find that they put more effort into studying, and are less fatigued by studying, it could be that finding ways to increase student motivation will improve student experiences while preparing for tests and exams. This could encourage longer, more effective study periods and contribute to undergraduate student success.

One of the original questions of our study was whether it could be the subjective experience of cognitive effort that influences students' study choices when preparing for tests or examinations. Ultimately, given that there were no significant differences in felt effort or fatigue in Study I, and that there were no significant differences in task difficulty, felt effort, or fatigue in Study II, it may not be conceptions of effort that guide a student's study decisions. Given that motivation was a critical factor in student experience, it could be that students could be selecting a strategy based on how motivated they are to study or to succeed in their courses, where those who are less motivated select a less effective strategy. The type of motivation that a student has may also be a factor. Studies have shown that first year undergraduates focus more on mastery and

enjoyment of their studies, whereas upper year undergraduates focus on performance on assessments (Lieberman & Remedios, 2007). This notion is supported by goal theory, which distinguishes between the sometimes-conflicting goals that students have between learning and performance (Simons et al., 2004). If this were the case, upper year students may persist with study strategies that yield effective performance on exams, such as rereading the material soon before an exam, rather than approaches such as retrieval practice that are effective in the long term.

Self-determination theory would also suggest that motivation could be a factor in student study choices. In one study, participants who were more internally focused were more confident and selected better learning strategies that those who were externally regulated (Simons et al., 2004). As an extension of this, it could be that effective internal focus in pursuit of goals leads to selection of a more effective strategy (such as retrieval practice) when studying.

Another possibility is that there are other factors, aside from effort and motivation, that play larger roles in student study decisions. For example, rereading is a strategy that requires little training or explanation (Dunlosky et al., 2013). It is possible that this ease of implementation influences study choices. There are also other factors such as student preferences, metacognitive awareness, and time limitations that may also factor into study decisions, and these should be investigated in future studies.

Conclusions and Further Directions

Although the second iteration of this study did address a few gaps from Study I, there are still areas for further consideration in this research. First, it would be interesting to expand the investigation of effort to different study strategies. There are

many other strategies that students may choose to use, such as highlighting, summarizing notes, use of keywords or mnemonics, among others (Dunlosky et al., 2013). In addition, these techniques are likely not used in isolation, and a student could employ many of these techniques together when preparing for a single assessment. For example, if a student's initial understanding is poor, it may be advantageous to first engage in rereading so that they can construct a coherent schema of what they wish to recall; it may be more difficult to retrieve a concept that is not fully understood. It would therefore be of interest to determine how student experiences of effort may differ with other study strategies.

There are a few other variables that could be considered in the context of this study, such as student familiarity with the study strategy they are using, metacognitive awareness, and student interest in the topic. To further study the relationship between fatigue and test performance, it would also be of interest to note the time of day that participants complete the study and their baseline fatigue to analyze if those variables impact test scores.

Taken together, my findings are mixed. There is no strong indication that students' subjective experiences differ as a result of the strategy (rereading or retrieval) that is used. This result suggests that further investigation is needed of the commonly accepted statement in the literature that retrieval is effective because it is effortful. While my results do not disprove this hypothesis, they do highlight the need for a clearer definition of what specifically is meant by effort in the literature.

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Appendix

Appendix A. Study Passage- Study I (Bridley et al., 2020)

Historical Perspectives on Mental Illness

Prehistoric and Ancient Beliefs

Prehistoric cultures often held a supernatural view of abnormal behavior and saw it as the work of evil spirits, demons, gods, or witches who took control of the person. This form of demonic possession was believed to occur when the person engaged in behavior contrary to the religious teachings of the time. Treatment by cave dwellers included a technique called **trephination**, in which a stone instrument known as a *trephine* was used to remove part of the skull, creating an opening. They believed that evil spirits could escape through the hole in the skull, thereby ending the person's mental affliction and returning them to normal behavior. Early Greek, Hebrew, Egyptian, and Chinese cultures used a treatment method called **exorcism** in which evil spirits were cast out through prayer, magic, flogging, starvation, noise-making, or having the person ingest horrible tasting drinks.

Greco-Roman Thought

Rejecting the idea of demonic possession, Greek physician, Hippocrates (460-377 B.C.), said that mental disorders were akin to physical disorders and had natural causes. Specifically, he suggested that they arose from brain pathology, or head trauma/brain dysfunction or disease, and were also affected by heredity. Hippocrates classified mental disorders into three main categories – melancholia, mania, and phrenitis (brain fever) and gave detailed clinical descriptions of each. He also described four main fluids or **humors** that directed normal functioning and personality – *blood* which arose in the heart, *black bile* arising in the spleen, *yellow bile* or *choler* from the liver, and *phlegm* from the brain. Mental disorders occurred when the humors were in a state of imbalance such as an excess of yellow bile causing frenzy/mania and too much black bile causing melancholia/depression. Hippocrates believed mental illnesses could be treated as any other disorder and focused on the underlying pathology.

Also important was Greek philosopher, Plato (429-347 B.C.), who said that the mentally ill were not responsible for their own actions and so should not be punished. He emphasized the role of social environment and early learning in the development of mental disorders and believed it was the responsibility of the community and their families to care for them in a humane manner using rational discussions. Greek physician, Galen (A.D. 129-199) said mental disorders had either physical or mental causes that included fear, shock, alcoholism, head injuries, adolescence, and changes in menstruation.

In Rome, physician Asclepiades (124-40 BC) and philosopher Cicero (106-43 BC) rejected Hippocrates' idea of the four humors and instead stated that melancholy arises from grief, fear, and rage; not excess black bile. Roman physicians treated mental disorders with massage and warm baths, with the hope that their patients be

as comfortable as possible. They practiced the concept of "*contrariis contrarius*", meaning opposite by opposite, and introduced contrasting stimuli to bring about balance in the physical and mental domains. An example would be consuming a cold drink while in a warm bath.

The Middle Ages – 500 AD to 1500 AD

The progress made during the time of the Greeks and Romans was quickly reversed during the Middle Ages with the increase in power of the Church and the fall of the Roman Empire. Mental illness was yet again explained as possession by the Devil and methods such as exorcism, flogging, prayer, the touching of relics, chanting, visiting holy sites, and holy water were used to rid the person of the Devil's influence. In extreme cases, the afflicted were confined, beat, and even executed. Scientific and medical explanations, such as those proposed by Hippocrates, were discarded at this time.

Group hysteria, or **mass madness**, was also seen in which large numbers of people displayed similar symptoms and false beliefs. This included the belief that one was possessed by wolves or other animals and imitated their behavior, called **lycanthropy**, and a mania in which large numbers of people had an uncontrollable desire to dance and jump, called **tarantism**. The latter was believed to have been caused by the bite of the wolf spider, now called the tarantula, and spread quickly from Italy to Germany and other parts of Europe where it was called **Saint Vitus's dance**.

Perhaps the return to supernatural explanations during the Middle Ages makes sense given events of the time. The Black Death or Bubonic Plague had killed up to a third, and according to other estimates almost half, of the population. Famine, war, social oppression, and pestilence were also factors. Death was ever present which led to an epidemic of depression and fear. Nevertheless, near the end of the Middle Ages, mystical explanations for mental illness began to lose favor and government officials regained some of
their lost power over nonreligious activities. Science and medicine were once again called upon to explain mental disorders.

The Renaissance – 14th to 16th Centuries

The most noteworthy development in the realm of philosophy during the Renaissance was the rise of **humanism**, or the worldview that emphasizes human welfare and the uniqueness of the individual. This helped continue the decline of supernatural views of mental illness. In the mid to late 1500s, Johann Weyer (1515-1588), a German physician, published his book, *On the Deceits of the Demons,* that rebutted the Church's witch-hunting handbook, the *Malleus Maleficarum*, and argued that many accused of being witches and subsequently imprisoned, tortured, hung, and/or burned at the stake, were mentally disturbed and not possessed by demons or the Devil himself. He believed that like the body, the mind was susceptible to illness.
Not surprisingly, the book was met with vehement protest and even banned from the church. It should be noted that these types of acts occurred not only in Europe but also

in the United States. The most famous example was the Salem Witch Trials of 1692 in which more than 200 people were accused of practicing witchcraft and 20 were killed.

The number of **asylums**, or places of refuge for the mentally ill where they could receive care, began to rise during the 16th century as the government realized there were far too many people afflicted with mental illness to be left in private homes. Hospitals and monasteries were converted into asylums. Though the intent was benign in the beginning, as they began to overflow patients came to be treated more like animals than people. In 1547, the Bethlem Hospital opened in London with the sole purpose of confining those with mental disorders. Patients were chained up, placed on public display, and often heard crying out in pain. The asylum became a tourist attraction, with sightseers paying a penny to view the more violent patients, and soon was called "Bedlam" by local people; a term that today means "a state of uproar and confusion" (https://www.merriam-webster.com/dictionary/bedlam).

Reform Movement – 18th to 19th Centuries

The rise of the **moral treatment movement** occurred in Europe in the late 18th century and then in the United States in the early 19th century. Its earliest proponent was Phillipe Pinel (1745-1826) who was assigned as the superintendent of la Bicetre, a hospital for mentally ill men in Paris. He emphasized the importance of affording the mentally ill respect, moral guidance, and humane treatment, all while considering their individual, social, and occupational needs. Arguing that the mentally ill were sick people, Pinel ordered that chains be removed, outside exercise be allowed, sunny and well ventilated rooms replace dungeons, and patients be extended kindness and support. This approach led to considerable improvement for many of the patients, so much so, that several were released.

Following Pinel's lead in England, William Tuke (1732-1822), a Quaker tea merchant, established a pleasant rural estate called the York Retreat. The Quakers believed that all people should be accepted for who they were and treated kindly. At the retreat, patients could work, rest, talk out their problems, and pray (Raad & Makari, 2010). The work of Tuke and others led to the passage of the County Asylums Act of 1845 which required that every county in England and Wales provide asylum to the mentally ill. This was even extended to English colonies such as Canada, India, Australia, and the West Indies as word of the maltreatment of patients at a facility in Kingston, Jamaica spread, leading to an audit of colonial facilities and their policies.

Reform in the United States started with the figure largely considered to be the father of American psychiatry, Benjamin Rush (1745-1813). Rush advocated for the humane treatment of the mentally ill, showing them respect, and even giving them small gifts from time to time. Despite this, his practice included treatments such as bloodletting and purgatives, the invention of the "tranquilizing chair," and a reliance on astrology, showing that even he could not escape from the beliefs of the time.

Due to the rise of the moral treatment movement in both Europe and the United States, asylums became habitable places where those afflicted with mental illness could recover. However, it is often said that the moral treatment movement was a

victim of its own success. The number of mental hospitals greatly increased leading to staffing shortages and a lack of funds to support them. Though treating patients humanely was a noble endeavor, it did not work for some and other treatments were needed, though they had not been developed yet. It was also recognized that the approach worked best when the facility had 200 or fewer patients. However, waves of immigrants arriving in the U.S. after the Civil War were overwhelming the facilities, with patient counts soaring to 1,000 or more. Prejudice against the new arrivals led to discriminatory practices in which immigrants were not afforded moral treatments provided to native citizens, even when the resources were available to treat them. Another leader in the moral treatment movement was Dorothea Dix (1802- 1887), a New Englander who observed the deplorable conditions suffered by the mentally ill while teaching Sunday school to female prisoners. She instigated the **mental hygiene movement**, which focused on the physical well-being of patients. Over the span of 40 years, from 1841 to 1881, she motivated people and state legislators to do something about this injustice and raised millions of dollars to build over 30 more appropriate mental hospitals and improve others. Her efforts even extended beyond the U.S. to Canada and Scotland.

Appendix B. Study Passage- Study II (Spielman et al., 2020)

Sleep is not a uniform state of being. Instead, sleep is composed of several different stages that can be differentiated from one another by the patterns of brain wave activity that occur during each stage. These changes in brain wave activity can be visualized using EEG and are distinguished from one another by both the frequency and amplitude of brain waves. Sleep can be divided into two different general phases: REM sleep and non-REM (NREM) sleep. **Rapid eye movement (REM)** sleep is characterized by darting movements of the eyes under closed eyelids. Brain waves during REM sleep appear very similar to brain waves during wakefulness. In contrast, **non-REM (NREM)** sleep is subdivided into three stages distinguished from each other and from wakefulness by characteristic patterns of brain waves. The first three stages of sleep are NREM sleep, while the fourth and final stage of sleep is REM sleep. In this section, we will discuss each of these stages of sleep and their associated patterns of brain wave activity.

[Note that psychologists originally identified four stages of non-REM sleep, but these were revised in 2008, resulting in just three distinct phases of NREM sleep. You will see that stage 3 of NREM sleep is sometimes presented as both stage 3 and stage 4 in various texts.]

NREM Stages of Sleep

The first stage of NREM sleep is known as stage 1 sleep. **Stage 1** sleep is a transitional phase that occurs between wakefulness and sleep, the period during which we drift off to sleep. During this time, there is a slowdown in both the rates of respiration and

heartbeat. In addition, stage 1 sleep involves a marked decrease in both overall muscle tension and core body temperature.

In terms of brain wave activity, stage 1 sleep is associated with both alpha and theta waves. The early portion of stage 1 sleep produces **alpha waves**, which are relatively low frequency (8–13Hz), high amplitude patterns of electrical activity (waves) that become synchronized. This pattern of brain wave activity resembles that of someone who is very relaxed, yet awake. As an individual continues through stage 1 sleep, there is an increase in theta wave activity. **Theta waves** are even lower frequency (4–7 Hz), higher amplitude brain waves than alpha waves. It is relatively easy to wake someone from stage 1 sleep; in fact, people often report that they have not been asleep if they are awoken during stage 1 sleep.

As we move into **stage 2 sleep**, the body goes into a state of deep relaxation. Theta waves still dominate the activity of the brain, but they are interrupted by brief bursts of activity known as sleep spindles (Figure 3). A **sleep spindle** is a rapid burst of higher frequency brain waves that may be important for learning and memory (Fogel & Smith, 2011; Poe, Walsh, & Bjorness, 2010). In addition, the appearance of K-complexes is often associated with stage 2 sleep. A **K-complex** is a very high amplitude pattern of brain activity that may in some cases occur in response to environmental stimuli. Thus, K-complexes might serve as a bridge to higher levels of arousal in response to what is going on in our environments (Halász, 1993; Steriade & Amzica, 1998).

Stage 3 of sleep is often referred to as deep sleep or slow-wave sleep because these stages are characterized by low frequency (up to 4 Hz), high amplitude **delta waves** (Figure 4). During this time, an individual's heart rate and respiration slow dramatically. It is much more difficult to awaken someone from sleep during stage 3 than during earlier stages. Interestingly, individuals who have increased levels of alpha brain wave activity (more often associated with wakefulness and transition into stage 1 sleep) during stage 3 often report that they do not feel refreshed upon waking, regardless of how long they slept (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008).

REM Sleep

As mentioned earlier, REM sleep is marked by rapid movements of the eyes. The brain waves associated with this stage of sleep are very similar to those observed when a person is awake, as shown in Figure 5, and this is the period of sleep in which dreaming occurs. It is also associated with paralysis of muscle systems in the body with the exception of those that make circulation and respiration possible. Therefore, no movement of voluntary muscles occurs during REM sleep in a normal individual; REM sleep is often referred to as paradoxical sleep because of this combination of high brain activity and lack of muscle tone. Like NREM sleep, REM has been implicated in various aspects of learning and memory (Wagner, Gais, & Born, 2001), although there is disagreement within the scientific community about how important both NREM and REM sleep are for normal learning and memory (Siegel, 2001). If people are deprived of REM sleep and then allowed to sleep without disturbance, they will spend more time in

REM sleep in what would appear to be an effort to recoup the lost time in REM. This is known as the REM rebound, and it suggests that REM sleep is also homeostatically regulated. Aside from the role that REM sleep may play in processes related to learning and memory, REM sleep may also be involved in emotional processing and regulation. In such instances, REM rebound may actually represent an adaptive response to stress in nondepressed individuals by suppressing the emotional salience of aversive events that occurred in wakefulness (Suchecki, Tiba, & Machado, 2012).

While sleep deprivation in general is associated with a number of negative consequences (Brown, 2012), the consequences of REM deprivation appear to be less profound (as discussed in Siegel, 2001). In fact, some have suggested that REM deprivation can actually be beneficial in some circumstances. For instance, REM sleep deprivation has been demonstrated to improve symptoms of people suffering from major depression, and many effective antidepressant medications suppress REM sleep (Riemann, Berger, & Volderholzer, 2001; Vogel, 1975).

It should be pointed out that some reviews of the literature challenge this finding, suggesting that sleep deprivation that is not limited to REM sleep is just as effective or more effective at
alleviating depressive symptoms among some patients suffering from depression. In either case, why sleep deprivation improves the mood of some patients is not entirely understood (Giedke & Schwärzler, 2002). Recently, however, some have suggested that sleep deprivation might change emotional processing so that various stimuli are more likely to be perceived as positive in nature

Dreams

The meaning of dreams varies across different cultures and periods of time. By the late 19th century, German psychiatrist Sigmund Freud had become convinced that dreams represented an opportunity to gain access to the unconscious. By analyzing dreams, Freud thought people could increase self-awareness and gain valuable insight to help them deal with the problems they faced in their lives. Freud made distinctions between the manifest content and the latent content of dreams.

Manifest content is the actual content, or storyline, of a dream. **Latent content**, on the other hand, refers to the hidden meaning of a dream. For instance, if a woman dreams about being chased by a snake, Freud might have argued that this represents the woman's fear of sexual intimacy, with the snake serving as a symbol of a man's penis.

Freud was not the only theorist to focus on the content of dreams. The 20th century Swiss psychiatrist Carl Jung believed that dreams allowed us to tap into the **collective unconscious**. The collective unconscious, as described by Jung, is a theoretical repository of information he believed to be shared by everyone. According to Jung,

certain symbols in dreams reflected universal archetypes with meanings that are similar for all people regardless of culture or location.

The sleep and dreaming researcher Rosalind Cartwright, however, believes that dreams simply reflect life events that are important to the dreamer. Unlike Freud and Jung, Cartwright's ideas about dreaming have found empirical support. For example, she and her colleagues published a study in which women going through divorce were asked several times over a five month period to report the degree to which their former spouses were on their minds. These same women were awakened during REM sleep in order to provide a detailed account of their dream content. There was a significant positive correlation between the degree to which women thought about their former spouses during waking hours and the number of times their former spouses appeared as characters in their dreams (Cartwright, Agargun, Kirkby, & Friedman, 2006). Recent research (Horikawa, Tamaki, Miyawaki, & Kamitani, 2013) has uncovered new techniques by which researchers may effectively detect and classify the visual images that occur during dreaming by using fMRI for neural measurement of brain activity patterns, opening the way for additional research in this area.

Recently, neuroscientists have also become interested in understanding why we dream. For example, Hobson (2009) suggests that dreaming may represent a state of protoconsciousness. In other words, dreaming involves constructing a virtual reality in our heads that we might use to help us during wakefulness. Among a variety of neurobiological evidence, John Hobson cites research on lucid dreams as an opportunity to better understand dreaming in general. **Lucid dreams** are dreams in which certain aspects of wakefulness are maintained during a dream state.

In a lucid dream, a person becomes aware of the fact that they are dreaming, and as such, they can control the dream's content (LaBerge, 1990).

Theories on Dreaming

While the Freudian theory of dreaming may be the most well known, and Cartwright's suggestions on dreaming the most plausible, there are several other theories about the purpose of dreaming. The **threat-simulation theory** suggests that dreaming should be seen as an ancient biological defense mechanism. Dreams are thought to provide an evolutionary advantage because of their capacity to repeatedly simulate potential threatening events. This process enhances the neurocognitive mechanisms required for efficient threat perception and avoidance.

The expectation-fulfillment theory posits that dreaming serves to discharge emotional arousals (however minor) that haven't been expressed during the day. This practice frees up space in the brain to deal with the emotional arousals of the next day and allows instinctive urges to stay intact. In effect, the expectation is fulfilled (the action is

"completed") in a metaphorical form so that a false memory is not created. This theory explains why dreams are usually forgotten immediately afterwards.

One prominent neurobiological theory of dreaming is the **activation-synthesis theory**, which states that dreams don't actually mean anything. They are merely electrical brain impulses that pull random thoughts and imagery from our memories. The theory posits that humans construct dream stories after they wake up, in a natural attempt to make sense of the nonsensical. However, given the vast documentation of the realistic aspects of human dreaming, as well as indirect experimental evidence that other mammals such as cats also dream, evolutionary psychologists have theorized that dreaming does indeed serve a purpose.

The **continual-activation theory** proposes that dreaming is a result of brain activation and synthesis. Dreaming and REM sleep are simultaneously controlled by different brain mechanisms. The hypothesis states that the function of sleep is to process, encode, and transfer data from short-term memory to long-term memory through a process called consolidation. However, there is not much evidence to back this up. NREM sleep processes the conscious-related memory (declarative memory), and REM sleep processes the unconscious related memory (procedural memory).

The underlying assumption of continual-activation theory is that, during REM sleep, the unconscious part of the brain is busy processing procedural memory. Meanwhile, the level of activation in the conscious part of the brain descends to a very low level as the inputs from the senses are basically disconnected. This triggers the "continual-activation" mechanism to generate a data stream from the memory stores to flow through to the conscious part of the brain.

Many people experience disturbances in their sleep at some point in their lives. Depending on
the population and sleep disorder being studied, between 30% and 50% of the population suffers from a sleep disorder at some point in their lives (Bixler, Kales, Soldatos, Kaels, & Healey, 1979;

This section will describe several sleep disorders as well as some of their treatment options.

Parasomnias

Sleepwalking

A **parasomnia** is one of a group of sleep disorders in which unwanted, disruptive motor activity and/or experiences *during* sleep play a role. Parasomnias can occur in either REM or NREM phases of sleep. Sleepwalking, restless leg syndrome, and night terrors are all examples of parasomnias (Mahowald & Schenck, 2000).

In **sleepwalking**, or somnambulism, the sleeper engages in relatively complex behaviors ranging from wandering about to driving an automobile. During periods of sleepwalking, sleepers often have their eyes open, but they are not responsive to attempts to communicate with them. Sleepwalking most often occurs during slow-wave sleep, but it can occur at any time during a sleep period in some affected individuals (Mahowald & Schenck, 2000).

Historically, somnambulism has been treated with a variety of pharmacotherapies ranging from benzodiazepines to antidepressants. However, the success rate of such treatments is questionable. Guilleminault et al. (2005) found that sleepwalking was not alleviated with the use of benzodiazepines. However, all of their somnambulistic patients who also suffered from sleep- related breathing problems showed a marked decrease in sleepwalking when their breathing problems were effectively treated.

REM Sleep Behavior Disorder (RBD)

REM sleep behavior disorder (RBD) occurs when the muscle paralysis associated with the REM sleep phase does not occur. Individuals who suffer from RBD have high levels of physical activity during REM sleep, especially during disturbing dreams. These behaviors vary widely, but they can include kicking, punching, scratching, yelling, and behaving like an animal that has been frightened or attacked. People who suffer from this disorder can injure themselves or their sleeping partners when engaging in these behaviors. Furthermore, these types of behaviors ultimately disrupt sleep, although affected individuals have no memories that these behaviors have occurred (Arnulf, 2012).

This disorder is associated with a number of neurodegenerative diseases such as Parkinson's disease. In fact, this relationship is so robust that some view the presence of RBD as a potential
aid in the diagnosis and treatment of a number of neurodegenerative diseases (Ferini-Strambi, 2011). Clonazepam, an anti-anxiety medication with sedative properties, is most often used to treat RBD. It is administered alone or in conjunction with doses of melatonin (the hormone secreted by the pineal gland). As part of treatment, the sleeping environment is often modified
to make it a safer place for those suffering from RBD (Zangini, Calandra-Buonaura, Grimaldi, &
Cortelli, 2011).

Other Parasomnias

A person with **restless leg syndrome** has uncomfortable sensations in the legs during periods of inactivity or when trying to fall asleep. This discomfort is relieved by deliberately moving the legs, which, not surprisingly, contributes to difficulty in falling or staying asleep. Restless leg syndrome

is quite common and has been associated with a number of other medical diagnoses, such as chronic kidney disease and diabetes (Mahowald & Schenck, 2000). There are a variety of drugs that treat restless leg syndrome: benzodiazepines, opiates, and anticonvulsants (Restless Legs Syndrome Foundation, n.d.).

Night terrors result in a sense of panic in the sufferer and are often accompanied by screams and attempts to escape from the immediate environment (Mahowald & Schenck, 2000). Although individuals suffering from night terrors appear to be awake, they generally have no memories of the events that occurred, and attempts to console them are ineffective. Typically, individuals suffering from night terrors will fall back asleep again within a short time. Night terrors apparently occur during the NREM phase of sleep (Provini, Tinuper, Bisulli, & Lagaresi, 2011). Generally, treatment for night terrors is unnecessary unless there is some underlying medical or psychological condition that is contributing to the night terrors (Mayo Clinic, n.d.).

Insomnia

While parasomnias are disorders related to the various stages of sleep, other sleep disorders, such as insomnia, are related to sleep in general. **Insomnia** is a consistent difficulty in falling or staying asleep, and is the most common of the sleep disorders. Individuals with insomnia often experience long delays between the times that they go to bed and actually fall asleep. In addition, these individuals may wake up several times during the night only to find that they have difficulty getting back to sleep. As mentioned earlier, one of the criteria for insomnia involves experiencing these symptoms for at least three nights a week for at least one month's time. It is not uncommon for people suffering from insomnia to experience increased levels of anxiety about their inability to fall asleep. This becomes a self-perpetuating cycle because increased anxiety leads to increased arousal, and higher levels of arousal make the prospect of falling asleep even more unlikely. Chronic insomnia is almost always associated with feeling overtired and may be associated with symptoms of depression.

There may be many factors that contribute to insomnia, including age, drug use, exercise, mental
status, and bedtime routines. Not surprisingly, insomnia treatment may take one of several different approaches. People who suffer from insomnia might limit their use of stimulant drugs (such as caffeine) or increase their amount of physical exercise during the day. Some people

might turn to over-the-counter (OTC) or prescribed sleep medications to help them sleep, but this should be done sparingly because many sleep medications result in dependence and alter the nature of the sleep cycle, and they can increase insomnia over time. Those who continue to have insomnia, particularly if it affects their quality of life, should seek professional treatment.

Some forms of psychotherapy, such as **cognitive-behavioral therapy**, can help sufferers of insomnia. Cognitive-behavioral therapy is a type of psychotherapy that

focuses on cognitive processes and problem behaviors. The treatment of insomnia likely would include stress management techniques and changes in problematic behaviors that could contribute to insomnia

(e.g., spending more waking time in bed). Cognitive-behavioral therapy has been demonstrated to be quite effective in treating insomnia.

Sleep Apnea

Sleep apnea is defined by episodes during which a sleeper's breathing stops. These episodes can last 10–20 seconds or longer and often are associated with brief periods of arousal. While individuals suffering from sleep apnea may not be aware of these repeated disruptions in sleep, they do experience increased levels of fatigue. Many individuals diagnosed with sleep apnea first seek treatment because their sleeping partners indicate that they snore loudly and/or stop breathing for extended periods of time while sleeping (Henry & Rosenthal, 2013). Sleep apnea is much more common in overweight people and is often associated with loud snoring. Surprisingly, sleep apnea may exacerbate cardiovascular disease. While sleep apnea is less common in thin people, anyone, regardless of their weight, who snores loudly or gasps for air while sleeping, should be checked for sleep apnea.

While people are often unaware of their sleep apnea, they are keenly aware of some of the adverse consequences of insufficient sleep. Consider a patient who believed that as a result of his sleep apnea he "had three car accidents in six weeks. They were ALL my fault. Two of them I didn't even know I was involved in until afterwards" (Henry & Rosenthal, 2013, p. 52). It is not uncommon for people suffering from undiagnosed or untreated sleep apnea to fear that their careers will be affected by the lack of sleep, illustrated by this statement from another patient, "I'm in a job where there's a premium on being mentally alert. I was really sleepy... and having trouble concentrating.... It was getting to the point where it was kind of scary"

There are two types of sleep apnea: **obstructive sleep apnea** and central sleep apnea. Obstructive sleep apnea occurs when an individual's airway becomes blocked during sleep, and air is prevented from entering the lungs. In **central sleep apnea**, disruption in signals sent from

the brain that regulate breathing cause periods of interrupted breathing (White, 2005). One of the most common treatments for sleep apnea involves the use of a special device during sleep. A **continuous positive airway pressure (CPAP)** device includes a mask that fits over the

sleeper's nose and mouth, which is connected to a pump that pumps air into the person's airways, forcing them to remain open, as shown in Figure 1. Some newer CPAP masks are smaller and cover only the nose. This treatment option has proven to be effective for people suffering from mild to severe cases of sleep apnea (McDaid et al., 2009). However, alternative treatment options are being explored because

consistent compliance by users of CPAP devices is a problem. Recently, a new EPAP (excitatory positive air pressure) device has shown promise in double-blind trials as one such alternative (Berry, Kryger, & Massie, 2011).

SIDS

In **sudden infant death syndrome (SIDS)** an infant stops breathing during sleep and dies. Infants younger than 12 months appear to be at the highest risk for SIDS, and boys have a greater risk than girls. A number of risk factors have been associated with SIDS including premature birth, smoking within the home, and hyperthermia. There may also be differences in both brain structure and function in infants that die from SIDS (Berkowitz, 2012; Mage & Donner, 2006; Thach, 2005).

The substantial amount of research on SIDS has led to a number of recommendations to parents to protect their children (Figure 2). For one, research suggests that infants should be placed on their backs when put down to sleep, and their cribs should not contain any items which pose suffocation threats, such as blankets, pillows or padded crib bumpers (cushions that cover the
bars of a crib). Infants should not have caps placed on their heads when put down to sleep in order to prevent overheating, and people in the child's household should abstain from smoking in the home. Recommendations like these have helped to decrease the number of infant deaths
from SIDS in recent years (Mitchell, 2009; Task Force on Sudden Infant Death Syndrome, 2011).

Narcolepsy

Unlike the other sleep disorders described in this section, a person with **narcolepsy** cannot resist falling asleep at inopportune times. These sleep episodes are often associated with **cataplexy**, which is a lack of muscle tone or muscle weakness, and in some cases involves complete paralysis

of the voluntary muscles. This is similar to the kind of paralysis experienced by healthy individuals during REM sleep (Burgess & Scammell, 2012; Hishikawa & Shimizu, 1995; Luppi et al., 2011). Narcoleptic episodes take on other features of REM sleep. For example, around one third of individuals diagnosed with narcolepsy experience vivid, dream-like hallucinations during narcoleptic attacks (Chokroverty, 2010).

Surprisingly, narcoleptic episodes are often triggered by states of heightened arousal or stress. The typical episode can last from a minute or two to half an hour. Once awakened from a narcoleptic attack, people report that they feel refreshed (Chokroverty, 2010). Obviously, regular narcoleptic episodes could interfere with the ability to perform one's job or complete schoolwork, and in some situations, narcolepsy can result in significant harm and injury (e.g., driving a car or operating machinery or other potentially dangerous equipment).

Generally, narcolepsy is treated using psychomotor stimulant drugs, such as amphetamines (Mignot, 2012). These drugs promote increased levels of neural activity. Narcolepsy is associated with reduced levels of the signaling molecule hypocretin in some areas of the brain (De la Herrán- Arita & Drucker-Colín, 2012; Han, 2012), and the traditional stimulant drugs do not have direct effects on this system. Therefore, it is quite likely that new medications that are developed to treat narcolepsy will be designed to target the hypocretin system.

There is a tremendous amount of variability among sufferers, both in terms of how symptoms of narcolepsy manifest and the effectiveness of currently available treatment options. This is illustrated by McCarty's (2010) case study of a 50-year-old woman who sought help for the excessive sleepiness during normal waking hours that she had experienced for several years. She indicated that she had fallen asleep at inappropriate or dangerous times, including while eating, while socializing with friends, and while driving her car. During periods of emotional arousal, the woman complained that she felt some weakness in the right side of her body. Although she did not experience any dream-like hallucinations, she was diagnosed with narcolepsy as a result of sleep testing. In her case, the fact that her cataplexy was confined to the right side of her body was quite unusual. Early attempts to treat her condition with a stimulant drug alone were unsuccessful. However, when a stimulant drug was used in conjunction with a popular antidepressant, her condition improved dramatically.

Appendix C. Test Questions- Study I

Who posited that there were four main humors?

a. Plato
b. Cicero
c. Hippocrates
d. Asclepiades

In greco-roman thought, where was phlegm said to arise?

a. Spleen
b. Liver
c. Heart
d. Brain

Which of the following is not one of the four humors?

a. Black bile
b. Red bile
c. Choler
d. Blood

An excess of black bile was said to cause:

a. Mania

b. Melancholy
c. Frenzy
d. Fear

Who is largely considered to be the father of American psychiatry?

a. Johann Weyer
b. William Tuke
c. Benjamin Rush
d. Galen

The County Asylums Act was passed in:

a. 1845
b. 1862
c. 1902
d. 1829

Who published the book “On the Deceits of Demons?

a. Johann Weyer
b. Clifford Beers
c. Dorothea Dix
d. Philippe Pinel

Which asylum was also used as a tourist attraction?
a. La Bicetre
b. Bethlem Hospital
c. York Retreat
d. Broadmoor Hospital

Supernatural explanations of mental illness were most favoured in these two time periods:

a. Prehistoric and Middle Ages
b. Greco-Roman and Middle Ages
c. Middle Ages and Renaissance
d. Prehistoric and Greco-Roman

What was said to cause Saint Vitus’s dance?

a. Evil spirits in the skull
b. Possession by a wolf
c. The bite of a spider
d. The four humors in a state of imbalance

Despite advocating for their humane treatment, _____ used dated techniques like bloodletting and purgatives to treat the mentally ill

a. Philippe Pinel
b. Dorothea Dix
c. Johann Weyer
d. Benjamin Rush

This prehistoric procedure allowed spirits to escape by removing part of the skull:

a. Trephination
b. Lycanthropy
c. Craniotomy
d. Exorcism

Who practiced the concept of contrariis contrarius?

a. Greeks
b. Chinese
c. Romans
d. Egyptians

Which book was banned by the Church because it refuted traditional religious views on mental illness:

a. Malleus Maleficarum
b. A Mind that Found Itself
c. On the Deceits of Demons
d. Conversations of Common Things

In prehistoric times, what stone instrument was used to remove part of person's skull?

a. Mochliskos

b. Trephine
c. Sikua
d. Kauterion

Those who plea criminally insane should probably thank:

a. Plato
b. Hippocrates
c. Socrates
d. Galen

Plato emphasized the role of ____ in the development of mental disorders:

a. Alcoholism
b. Humane families
c. Rational discussion

d. Social environment

Hippocrates classified mental disorders into three main categories:

a. Depressions, anxieties, and stressors
b. Black bile, yellow bile, and phlegm
c. Melancholia, phrenitis, mania
d. Grief, sadness, and fear

Asclepiades and Cicero rejected the idea that the four humors:

a. Led to melancholy
b. Led to excess black bile
c. Led to grief
d. Could be balanced with massage

Roman physicians treated mental illness primarily:

a. At the physical level
b. At the spiritual level
c. At an emotional level
d. With yellow bile

In the Middle Ages, the treatment of mental disorders:

a. Went through rapid advancements
b. Relied heavily on the scientific method
c. Were based on natural explanations
d. Were based on supernatural explanations

A return to supernatural beliefs might be partially attributable to:

a. The black death
b. Group hysteria
c. The fall of the church
d. Exorcism and flogging

Tarantism occurs:

a. When bitten by a wolf
b. When bitten by a spider
c. When honoring Saint Vitus
d. During community dances

Humanist philosophy was one of the many notable developments during:

a. The Middle Ages
b. The rise of the Romans

c. The Renaissance
d. The Malleus Maleficarum

The moral treatment movement occurred:

a. In Europe in the early 18th century and USA in the late 19th century. b. In Europe in the late 18th century and USA in the early 19th century. c. In Europe in the late 19th century and USA in the early 18th century. d. In Europe in the early 19th century and USA in the late 18th century.

Pinel argued that the mentally ill:

a. Just needed fresh air
b. Should be kept at la Bicetre
c. Deserved respect
d. Should not be put in asylums because they were immoral

William Tuke is famous for:

a. The Quaker Oats company
b. For being a tea merchant
c. For creating the York Retreat
d. Suggesting that prayer can cure mental illness

The County Asylums Act:

a. Mandated the construction of a facility in Kingston
b. Outlawed asylums in all countries
c. Mandated that every country in England and Wales provide asylum to the mentally ill d. Was written by William Tuke

The moral treatment movement:

a. Was ultimately a failure
b. Succeeded until the US Civil War
c. Relied on the pseudoscience of astrology
d. Was said to be a victim of its own successes

The mental hygiene movement:

a. Raised money to help build asylums
b. Focused on the physical wellbeing of patients
c. Became popular in many different countries
d. Emphasized the importance of Sunday school for female prisoners

Appendix D. Test Questions- Study II

	Test 1	Test 2
1	What technique can be used to detect and classify visual images during dreams? a. Magnetic resonance imaging (MRI) b. Positron-emission tomography (PET) c. Computed tomography (CT) d. Functional magnetic resonance imaging (fMRI)	How do scientists visualize brain wave activity? a. Functional magnetic resonance imaging (fMRI) b. Computerized tomography (CT) c. Electroencephalography (EEG) d. Magnetoencephalography (MEG)
2	How many stages of non-REM (NREM) sleep were originally identified by psychologists, and what was this number revised to? a. Three, five b. Four, three c. Five, four d. Two, three	When were the stages of non-REM (NREM) sleep revised by psychologists? a. 1967 b. 1995 c. 2008 d. 2012
3	The brain activity in stage 2 sleep is dominated by: a. Alpha waves b. Beta waves c. Theta waves d. Delta waves	The brain activity in stage 3 sleep is dominated by: a. Alpha waves b. Beta waves c. Theta waves d. Delta waves
4	K-complexes are typically associated with which stage of sleep? a. Stage 1 sleep b. Stage 2 sleep c. Stage 3 sleep d. REM sleep	What is a K-complex? a. A high amplitude pattern of brain activity that can occur in response to environmental stimuli b. A low amplitude pattern of brain activity marked physiologically by decreased heart rate and breathing rate c. A low amplitude pattern of brain activity that occurs during stage 3 of sleep

		d. A high amplitude pattern of brain activity that occurs during REM sleep
5	The brain waves associated with someone in REM sleep are similar to: a. Someone who is awake b. Someone in stage 1 sleep c. Someone in stage 2 sleep d. Someone in stage 3 sleep	REM sleep is sometimes referred to as: a. Dream sleep b. Paralysis sleep c. Paradoxical sleep d. Adaptive sleep
6	What term is used to describe rapid bursts of higher frequency brain waves? a. Sleep sporadicity b. Sleep spindle c. K-complex d. Neural movement	In what stage of sleep are theta waves interrupted by brief bursts of sleep spindles? a. Stage 1 b. Stage 2 c. Stage 3 d. Stage 4
7	Alpha waves are: a. Low frequency and low amplitude waves b. Low frequency and high amplitude waves c. High frequency and low amplitude waves d. High frequency and high amplitude waves	Which type of brain wave activity resembles someone who is awake but very relaxed? a. Alpha waves b. Beta waves c. Theta waves d. Delta waves
8	Which psychologist believed that dreams reflect life events that are important to the dreamer? a. Sigmund Freud b. Carl Jung c. Rosalind Cartwright d. John Hobson	Which theorist believed that dream analysis could give individuals insight into dealing with their problems? a. Sigmund Freud b. Carl Jung c. Rosalind Cartwright d. John Hobson
9	Which theory suggests that dreaming can improve efficient threat perception and avoidance? a. Threat-simulation theory b. Expectation-fulfillment theory c. Activation-synthesis theory d. Continual-activation theory	Which theory explains why dreams are usually forgotten afterwards? a. Threat-simulation theory b. Expectation-fulfillment theory

		c. Activation-synthesis theory d. Continual-activation theory
10	Which theory suggests that dreams are created after waking up? a. Threat-simulation theory b. Expectation-fulfillment theory c. Activation-synthesis theory d. Continual-activation theory	Which theory states that data is transferred from short-term to long-term memory during sleep? a. Threat-simulation theory b. Expectation-fulfillment theory c. Activation-synthesis theory d. Continual-activation theory
11	What type of memory does REM sleep process? a. Declarative memory b. Deductive memory c. Peripheral memory d. Procedural memory	Which type of memory does NREM sleep process? a. Declarative memory b. Deductive memory c. Peripheral memory d. Procedural memory
12	When do parasomnias occur? a. REM sleep b. NREM sleep c. REM or NREM sleep d. Before sleep	Which of the following is not an example of parasomnias? a. Sleepwalking b. Obstructive sleep apnea c. REM sleep behaviour disorder d. Night terrors
13	What medication is typically used to treat REM sleep behaviour disorder? a. Clonazepam b. Fluoxetine c. Paroxetine d. Sertraline	What type of drugs are NOT typically used to treat restless leg syndrome? a. Amphetamines b. Anticonvulsants c. Benzodiazepines d. Opiates
14	Which of the following sleep disorders is the most common? a. Restless leg syndrome b. REM sleep behaviour disorder c. Sleep apnea d. Insomnia	How often does someone have to experience symptoms of insomnia to be diagnosed? a. At least three nights a week for two weeks

		b. At least four nights a week for two weeks c. At least three nights a week for one month d. At least four nights a week for one month
15	At what age are infants at the highest risk for sudden infant death syndrome? a. Younger than 3 months b. Younger than 6 months c. Younger than 9 months d. Younger than 12 months	Which of the following is not a risk factor for SIDS? a. Gender b. Premature birth c. Smoking within the home d. Exposure to air pollution
16	Narcolepsy is associated with reduced levels of which molecule? a. Acetylcholine b. Histamine c. Hypocretin d. Neurotensin	What type of drug is typically used to treat narcolepsy? a. Amphetamines b. Antidepressants c. Benzodiazepines d. Opiates
17	How much of the population suffers from a sleep disorder at some point in their lives? a. Between 15% and 40% b. Between 20% and 60% c. Between 30% and 50% d. Between 40% and 55%	Approximately how many individuals diagnosed with narcolepsy experience vivid, dream-like hallucinations? a. 20% b. 25% c. 33% d. 50%
18	Narcoleptic episodes typically resemble features from which stage of sleep? a. Stage 1 sleep b. Stage 2 sleep c. Stage 3 sleep d. REM sleep	When does sleepwalking most often occur? a. Stage 1 sleep b. Stage 2 sleep c. Stage 3 sleep d. REM sleep
19	Which of the following groups of individuals is sleep apnea is most common in? a. Older individuals b. Younger individuals c. Overweight individuals d. Thinner individuals	What term is used to describe a lack of muscle tone or muscle weakness? a. Acatalepsy b. Cataplexy c. Coloplexy d. Narcolepsy

20	Hobson believed that dreaming may represent a state of: a. Proconsciousness b. Preconsciousness c. Protoconsciousness d. Postconsciousness	Some psychoanalysts believe that dreams allow us to tap into the collective unconscious. This idea was championed by a. Sigmund Freud b. Carl Jung c. Rosalind Cartwright d. John Hobson
21	Which of the following is the description of continual activation theory? a. During REM sleep, the unconscious part of the brain processes procedural memory and activation in the conscious part of the brain decreases to a low level b. During NREM sleep, the conscious part of the brain processes procedural memory and activation in the unconscious part of the brain decreases to a low level c. During REM sleep, the conscious part of the brain processes procedural memory and activation in the unconscious part of the brain decreases to a low level d. During NREM sleep, the unconscious part of the brain processes procedural memory and activation in the conscious part of the brain decreases to a low level	Which of the following disorders is associated with a number of neurodegenerative diseases? a. Sleepwalking b. REM sleep behaviour disorder c. Restless leg syndrome d. Night terrors
22	When do night terrors typically occur? a. NREM sleep b. REM sleep c. NREM or REM sleep d. Before sleep	What is the process from which data is transferred to short-term to long-term memory? a. Conformation b. Combination c. Consolidation d. Cumulation
23	The REM rebound suggests that REM sleep is: a. Thermostatically regulated b. Chemically regulated c. Homeostatically regulated d. Environmentally regulated	Which stage of sleep does dreaming occur? a. Stage 1 sleep b. Stage 2 sleep c. Stage 3 sleep

		d. REM sleep
24	Which refers to the content, or storyline, of a dream? a. Manifest content b. Active content c. Passive content d. Latent content	Which refers to the hidden meaning of a dream? a. Manifest content b. Active content c. Passive content d. Latent content
	24 knowledge questions	
1	Doctors found that Valeria's airway was becoming blocked while she slept. When she goes to the doctor to address her concerns, they would likely diagnose her with? a. Obstructive sleep apnea b. Restrictive sleep apnea c. Interspersed sleep apnea d. Central sleep apnea	Doctors discovered that Preeti had periods of interrupted breathing while sleeping. What would they likely diagnose her with? a. Obstructive sleep apnea b. Restrictive sleep apnea c. Interspersed sleep apnea d. Central sleep apnea
2	Jill reports that her partner Jack often wakes her up in the middle of the night from his kicking, punching, and yelling. Which sleep disorder does Jack likely have? a. Sleepwalking b. REM sleep behaviour disorder c. Narcolepsy d. Sleep apnea	Thomas was told by his partner that last night, he had jolted awake last night and screamed shortly before falling back asleep. His partner told him that he was inconsolable but Thomas does not recall this happening. Thomas likely has which type of sleep disorder? a. Sleepwalking b. REM sleep behaviour disorder c. Night terrors d. Insomnia
3	Sarah was telling her friend Blake about her dream where she was running from a monster in an unknown city. Blake suggests that this might be because she is worried about moving across the country. Blake's suggestion would be an example of: a. Manifest content b. Active content c. Passive content	If Jim dreamt of his house burning down and saving his dog, this would be an example of: a. Manifest content b. Active content c. Passive content d. Latent content

	d. Latent content	
4	Jessica has a dream where she is trapped in the trunk of a car and must try to escape. This type of dream would best align with which theory? a. Threat-simulation theory b. Expectation-fulfillment theory c. Activation-synthesis theory d. Continual-activation theory	Leslie has recently put on weight and is constantly told that she needs to eat healthier by her family and friends. In her dream, she sees everyone as different bags of candy and chocolate. Her dream is an example of which of the following theories? a. Threat-simulation theory b. Expectation-fulfillment theory c. Activation-synthesis theory d. Continual-activation theory
5	Theodore had a dream where he stared out into the abyss with light shining all around them. The idea that the light may represent hope or renewal aligns with which of the following theorist's ideas? a. Sigmund Freud b. Carl Jung c. Rosalind Cartwright d. John Hobson	Kathy has been having dreams about failing her final calculus exam. The idea that she is having these dreams because the outcome of the exam is important to her aligns with which of the following theorist's ideas? a. Sigmund Freud b. Carl Jung c. Rosalind Cartwright d. John Hobson
6	Rachel's sister often complains that Rachel snores loudly and gasps often while sleeping. Which sleep disorder may Rachel have? a. REM sleep behaviour disorder b. Night terrors c. Sleep apnea d. Narcolepsy	Susan goes to the doctor because she is having issues with her sleep. Tests reveal that she has low levels of hypocretin. Which sleep disorder may Susan have? a. REM sleep behaviour disorder b. Night terrors c. Narcolepsy d. Sleep apnea

7	Oliver is suffering from insomnia. Which of the following might his doctor suggest for treatment? a. Decreasing physical exercise during the day b. Prescribe sleep medications to help Oliver fall asleep every night c. Forms of psychotherapy, including cognitive-behavioural therapy d. Increasing the use of stimulants such as caffeine in the morning so that he does not fall asleep during the day	Jane has narcolepsy. Which of the following could trigger a narcoleptic episode? a. She didn't sleep well the night before and is tired b. Reading a book and drinking tea on her couch c. She becomes stressed while studying for an upcoming PSYCH 1X03 exam d. There are no known triggers for narcolepsy since a person with narcolepsy cannot help but fall asleep at inopportune times
8.	Margaret is a new mother worried about SIDS. What might her doctor recommend to lower the risk of SIDS in her son? a. Use padded crib bumpers to prevent the child from hitting their head b. Dressing the child in a hat at night to prevent them from overheating c. Have Margaret co-sleep with her child so that she can watch him for signs of trouble d. Placing the child on their back before bed each night	Marshall has been suffering from night terrors. When he goes to the doctor, what might the doctor suggest for treatment? a. A combination of melatonin and clonazepam b. Forms of psychotherapy, including cognitive-behavioural therapy c. The use of a CPAP machine to control his breathing during his terrors d. No treatment is required for Marshall's night terrors
	8 application questions	

Appendix E. Study Instructions- Study I and II

Instruction- Rereading (General overview before reading the passage)
For this part of the study, please read the following passage and aim to remember as much information as possible. After you read the passage once, you will be given a 10-minute study period. You will be tested on the information found in the passage.

In addition, students often find that they do not have time to take notes on their readings. While the reading material here will be shorter than one found in a typical textbook, we ask that you simply read the passage and do not take notes, so that the experiment more closely mimics students' experiences.

Instruction- Rereading (entering study phase)
You are now entering the study phase. You will be given 10 minutes to re-read the passage and remember as much information as you can for the memory test. **Do not** write any content down; prepare for the memory test by re-reading the passage until all of your time has elapsed.

Instructions- Retrieval
For this part of the study, please read the following passage once and aim to remember as much information as possible. After you have finished the reading, you will have a 10-minute recall period. You will be tested on the information found in the passage.

In addition, students often find that they do not have time to take notes on their readings. While the reading material here will be shorter than one found in a typical textbook, we ask that you simply read the passage and do not take notes, so that the experiment more closely mimics students' experiences.

Instruction- Retrieval (entering study phase)
You are now entering the study phase. You will be given 10 minutes to recall as much information from the passage as you can. Please use the text box below to type all of the information you can remember, or any details you feel are relevant. Continue to recall as much information as possible until your time has elapsed. **Do not** refer to any other materials, or the passage, during this recall period.

Distractor Task- Operation Span Task Instructions
During this task, you will be presented with a series of equation-word pairs. An example of what you see on the screen could be (93+6=?, apple). For each pair, read the equation aloud and state the answer, then say the word printed beside the equation. After you have been given all equation-word pairs, you will have to state each of the words presented to you in the correct order.

Test Instructions
You will now be asked to complete a multiple-choice test that assesses your knowledge of the content of both passages you have studied. **Do not** refer to your notes or any other materials. You have 10 minutes to complete the test.

Note: **Instructions for Study II are the same, with the OSpan task eliminated and 15-minute reading and study periods**

Appendix F. Study Probes- Study I and II

Pre-experiment:

Please provide your age in the box below. If you do not want to answer, please type "prefer not to answer."

Please provide your gender in the box below. If you do not want to answer, please type "prefer not to answer."

Post-reading:

How difficult did you find it to understand the reading?
1 – not at all difficult 2 3 4 5 6 7 – extremely difficult

Post-studying:

The wording shifts slightly according to whether participants just completed the block of retrieval practice (in which case it will say "retrieve") or the block of rereading (in which case it will say "reread").

Please indicate how often you had each of the following experiences **while you were in the study phase**. A score of 1 indicates that you did not have this experience at all, while a score of 7 means that you had this experience the whole time you were studying the passage. Please ensure that you answer all of these questions honestly.

1) I was able to completely focus without straining to pay attention.

1 – Never 2 3 4 5 6 7 – Always

2) I seemed to reach a level of deep focus almost effortlessly.

1 – Never 2 3 4 5 6 7 – Always

3) I got in the zone and didn't have to force myself to concentrate.

1 – Never 2 3 4 5 6 7 – Always

4) How draining (i.e. fatiguing) did you find it to retrieve/reread the material?

1 – None 2 3 4 5 6 7 – A lot

5) How much effort did you put into rereading/retrieving the material?

1 – None 2 3 4 5 6 7 – A lot

6) How difficult did you find it to retrieve/reread the material?

1 – Never 2 3 4 5 6 7 – Always

Post-experiment

7) How motivated were you to learn the material?
1 – not at all motivated 2 3 4 5 6 7 – highly motivated