SELF-REGULATED LEARNING IN A COLLEGE COURSE: EXAMINING STUDENT METACOGNITIVE STUDY STRATEGIES, GRIT, SELF-EFFICACY, AND PERFORMANCE

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A goal of cognitive and educational psychology is to understand how people learn. Much progress has been made in separately identifying the motivations and learning strategies that impact student learning. However, it is unclear how these motivations and strategies relate with each other over time. The goal of this dissertation was to integrate and expand upon these separate lines of prior work in an educational context, the college classroom. In the first part of this dissertation, I examined the types of study strategies students reported prior to three separate exams and their subsequent exam performance. Students spontaneously reported using a variety of study strategies. Only a subset of those strategies was related to exam performance and those relations differed across the exams. In the second part, I examined the relation of these study strategies within a self-regulated learning framework. Specifically, I investigated the relations amongst students' grit, study strategies, exam performances, and self-efficacy for the course. Student's initial grit was positively related to using more constructive strategies, self-efficacy for the course, and exam performance. However, the relation between grit and exam performance was mediated by more proximal factors such as constructive strategy use. This finding suggests that although grit is associated with beneficial learning outcomes, it is mediated by other more proximal factors. In the third part, I evaluated whether these relations held true when a students' ethnic background (minority vs. majority) was entered as a moderator. There was a trend in which some of the relations between grit and performance were not present for students from underrepresented ethnic backgrounds. Taken together, this work suggests that a student does not have to be gritty to be self-regulated as the use of constructive strategies and self-efficacy beliefs can assist students in obtaining those outcomes, especially for students from underrepresented ethnic backgrounds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

I never thought that I would be on the path to obtaining my Ph.D. in Cognitive Psychology. While there are antecedents of this path in my earlier years with my interests in teaching and learning, this path started to become evident through my involvement with UC San Diego's Education Studies Program (Caren Holtzman, Susan Scharton, Rusty Bresser, Luz Chung – you were and are such amazing instructors), and my undergraduate research experiences at UC San Diego with Gail Heyman and UC Santa Cruz with Maureen Callanan. These experiences led me to follow my curiosity and purse a post-baccalaureate experience at the University of Pittsburgh with Tim Nokes-Malach. From that experience and my interactions with my labmates, Matt Bernacki and Liz Richey, I was hooked. Learning how others learn, figuring out ways to improve learning, and understanding how to motivate students to learn intrigued me. Back in the day, I didn't know that this type of career was possible, but I am so grateful for those that helped me to find this path, expanded my way of thinking, and provided opportunities for growth. To the tremendous community that has supported me on this journey, thank you.

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I share much of this achievement with my husband, Andrew, who has listened to me talk about metacognition, distributions, and self-regulated learning with honest enthusiasm. You have always been encouraging, starting with the submission of my HMB application back in 2011. Thank you for the reality checks when I was worried about a deadline or a talk. Thank you for embracing my research interests by incorporating them into all our sports-related endeavors. I am thankful to have experienced this milestone with you. Now off to Wash U we go.

1.0 INTRODUCTION

A goal of cognitive and educational psychology is to understand how people learn and how they regulate their learning. Much progress has been made in separately identifying the motivations and learning strategies that impact student learning (Koedinger, Booth, & Klahr, 2013; Schunk, Pintrich, & Meece, 2014). However, it is unclear how these motivations and strategies relate with each other and learning outcomes over a semester. Which study strategies do students use when preparing for an exam? Do students report similar strategies across each exam? Does this strategy use relate to their initial and subsequent motivations, and exam performance? Prior work has revealed that students generally prefer using less effective study strategies such as rereading (Karpicke, Butler, & Roediger, 2009). Another strand of research has revealed that students' motivations relate to their general strategy use for studying (e.g., how motivated are students and how does this relate to how students generally study for their courses; Hussain & Wolters, 2015) (Wolters & Hussain, 2015). The goal of this dissertation was to integrate and expand upon these separate lines of prior work in an educational context, the college classroom.

Self-regulated learning (SRL) theories are a set of frameworks that integrate student study strategies and motivations to understand learning (Garcia & Pintrich, 1994; Winne & Hadwin, 1998, 2008; Zimmerman, 2008). These theorists hypothesize that these factors work together to produce learning gains in which they affect each other within one cycle of learning. These interactions then affect later cycles of learning. However, there are few empirical tests that evaluate the iterative relations of SRL over time. The majority of prior SRL work focuses on how students' general study strategies and motivations relate to a larger grain size of learning such as GPA (Wolters & Hussain, 2015) or course grade (Bembenutty, 2007). To test SRL theories and their predictions for how study strategies and motivations work together over time, I measured students' study strategies and motivations at different time points during a semester for a college psychology course. This approach allowed for testing how students' strategies unfold over a semester, the relations between motivations and study strategies to each other and learning outcomes, and the iterative nature of these relations.

To understand how students used study strategies throughout the course, in the second chapter, I examined the types of study strategies students used to study for three separate exams and their subsequent exam performance. Unlike prior work, I used an open-ended question that asked about study strategies as well as a mixture of forced-choice and Likert-scale items. The open-ended question provided insight into which strategies are most salient and spontaneously generated by the students. In contrast, the forced-choice and Likert-scale items required students to respond to a question and provided insight about specific dimensions that students may not have previously considered as a study strategy. Using these different measures provided a more holistic view of student's beliefs about their strategies. These measures also allowed for the comparison between different questions assessing the same construct. For example, I examined the relation between students open-ended self-reports that they monitored their understanding and Likert-scale items that asked students whether they used this strategy.

To integrate this work with motivation, in the third chapter, I examined the relation of these study strategies in the context of a self-regulated learning framework. Specifically, I examined the relation of students' initial grit, their reported use of these strategies, their performances, and their self-efficacy for the course. There were several affordances to examining these relations across a semester. The longitudinal design provided an opportunity to test whether the observed pattern of relations would be replicated at multiple points throughout the semester and whether these relations replicated at different points across a semester. This design also allowed for testing SRL theory that predicts more proximal and context-specific measures mediate the relations between dispositional traits on performance outcomes. Additionally, this approach addressed the gap in the literature on the grain size of self-regulated learning. Prior work has examined self-regulated learning focusing on one iteration (e.g., increasing student metacognition increases motivation, Zepeda, Richey, Ronevich, & Nokes-Malach, 2015) or examining whether metacognitive and motivational measures at one time point are related to each other (Coutinho, 2008; Somuncuoglu & Yildirim, 1999). Other work examined self-regulated learning over multiple iterations but on one specific task (e.g., verbal protocols or log data; Bernacki, Nokes-Malach, & Aleven, 2015; Moos, 2011, 2014; Moos & Azevedo, 2009). This work bridges those approaches to examine how SRL functions over a course in which there are multiple points in which the metacognitive and motivational components are assessed and related to exam performance (e.g., several learning events that are evaluated by cumulative assessments).

Do these same patterns of results hold true when examining student populations that have traditionally more institutional challenges? To address this question, in the fourth chapter I evaluate whether the racial and ethnic backgrounds of students moderate the relation of grit on performance. Prior work examining the theoretical underpinnings and instantiations of increasing student grit have been argued to be inherently biased (Golden, 2017; Schreiner, 2017). Unlike the majority, traditionally underrepresented minorities have several barriers they encounter such as implicit biases from the institutions and economic disparities (Solorzano, Ceja, & Yosso, 2000; Yosso, Smith, Ceja, & Solórzano, 2009). Therefore, students from underrepresented minorities might have to spread their grit across a disproportional amount of challenges in comparison to the represented majority. These additional challenges may also dampen students' grit ratings as they are often challenged to put their grit to the test. To support this hypothesis, some work (Akos & Kretchmar, 2017) has also found that underrepresented populations endorsed lower grit ratings than their White counterparts. Given that the psychological science tends to be westernized, educated, industrialized, rich and democratic ("WEIRD"; Henrich, Heine, & Norenzayan, 2010; Jones, 2010) in the types of populations they examine and that cognitive science tends rarely measures (let alone controls for) ethnic/racial backgrounds of participants, I specifically examined whether grit operated differently for underrepresented minorities. Although there are several articles that discuss the inequity within grit (e.g., being gritty to overcome threats to one's identity instead of fixing the marginalizations and biases within a university; Golden, 2017; Schreiner, 2017), there are no studies that empirically evaluate whether grit functions differently for underrepresented minorities within a college course.

This dissertation has implications for theory, measurement, and future intervention work. Although past work has identified effective learning strategies in laboratory settings (e.g., Roediger & Karpicke, 2006), it is not clear how these strategies translate into the classroom and student practices. Therefore, obtaining insight into students' initial beliefs about strategies and how those beliefs relate to their learning and motivational outcomes is a necessary first step in identifying productive areas to intervene. These findings can serve as a baseline for future work that aims to enhance student learning and motivation.

2.0 METACOGNITIVE STUDY STRATEGIES IN A COLLEGE COURSE

When preparing for an exam or quiz, students can engage in several types of study strategies, some of which are more effective than others. Student awareness of the types of strategies they use and their judgments of which strategies are better than others reflects their metacognitive study strategies. Prior studies have shown that students do not know which strategies are more effective and tend to use less effective study strategies (Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Kornell & Bjork, 2007; McCabe, 2011; Wissman, Rawson, & Pyc, 2012). For example, students will tend to reread text or their notes versus quizzing themselves (Karpicke et al., 2009) or they choose to cram the day before the exam instead of spacing out their study (Susser & McCabe, 2013). These studies have examined how students generally think about using strategies and prompt students to make judgments on specific strategies in laboratory settings. For example, Karpicke et al. (2009) asked students how they study for their courses with an open-ended question (general) and then asked them to imagine they were taking an exam and to select one of three options: rereading, practicing recall, or another study activity for how they would study for that exam (prompted).

While there are benefits to these approaches (e.g., determining students' awareness and values of different strategies), they are not able to evaluate how students use strategies to study in-vivo (e.g., for a particular course exam) nor do they capture the changes in students reporting these strategies over time. A student may believe that rereading for an exam is more useful than quizzing themselves, but they might also be engaging in both processes to study for an exam.

That student might recognize that one strategy was more helpful than the other and adjust their strategies accordingly when preparing for the next exam. Furthermore, these approaches to measuring student study strategies may also prompt students to reflect on strategies that they may generally use or think they use, resulting in overconfidence.

To address these limitations, in this work I examined students' self-reports on the types of strategies they employed for different exams across a semester. This approach had several affordances. First, it revealed the strategies students think are critical for studying for an exam, which can provide a baseline for future intervention work or classroom scaffolding. Second, unlike the prior work examining student's metacognitive study strategies, this work broadened the strategies to include other learning strategies that are studied in educational contexts such as self-explanations (Chi, De Leeuw, Chiu, & Lavancher, 1994; Nokes-Malach, VanLehn, Belenky, Lichtenstein, & Cox, 2013; Nokes, Hausmann, VanLehn, & Gershman, 2011; Rittle-Johnson, 2006), metacognitive monitoring (Nietfeld, Cao, & Osborne, 2006; Rawson, O'Neil, & Dunlosky, 2011; Tobias & Everson, 2002), and analogical comparisons (Alfieri, Nokes-Malach, & Schunn, 2013; Gentner, Loewenstein, Thompson, & Forbus, 2009; Nokes-Malach et al., 2013). Third, it assessed whether students were consistent in their strategy use across the exams. Fourth, it provided an opportunity to examine how these strategies were related to exam performance. Integrating prior work on study strategies (e.g., Karpicke et al., 2009) and other empirical work on instructional techniques that promote learning (e.g., self-explanations and analogical comparisons, Richey & Nokes-Malach, 2015), I examined three aspects of their study strategy descriptions: the study strategies, the resource used, and time management.

2.1 PROCESSING - HOW THEY STUDY

Students can engage in a variety of learning activities that entail different levels of engagement. According to the Interactive, Constructive, Active, and Passive (ICAP) framework (formerly referred to as the differentiated overt learning activities (DOLA) framework), learning activities can entail passive, active, constructive, or interactive engagement (Chi, 2009; Chi & Wylie, 2014; Menekse, Stump, Krause, & Chi, 2013). Passive activities involve receiving information. Active activities involve attending to and manipulating the given information, such that attending processes are initiated to activate prior knowledge, search current knowledge, and assimilate, encode, or store new information. Constructive activities involve generating information beyond what is presented such that a cognitive process is initiated to infer new knowledge, integrate information with prior knowledge, organize, repair or restructure one's knowledge. Interactive activities involve engaging in dialogue with another person(s) about the information in which learners are jointly creating and incorporating each other's contributions. Each level of engagement subsumes the prior level such that the constructive activities also entail attending processes that occur within active activities.

The ICAP framework has built-in hypotheses in which these levels of engagement are predicted to result in different levels of understanding and performance (Chi & Wylie, 2014; Menekse, Stump, Krause, & Chi, 2013). Passive engagement is predicted to be related to minimal understanding. Active engagement is predicted to be related to shallow understanding. Constructive engagement is predicted to be related to deeper understanding that might transfer, and interactive engagement is predicted to be related to understanding that might create novel ideas. Some work has shown that interactive and constructive activities result in better learning and transfer of information than active and passive activities, and active activities lead to better learning outcomes than passive activities (Coleman et al., 1997; Menekse et al., 2013). Critically, within this line of research, the learning activities produced overt behaviors and were not based on students' self-reports of their behaviors. This raises the question as to whether one would observe similar outcomes for students self-reported study strategies? Therefore, in this work, I examined whether the ICAP distinctions could be applied to students' reports of their study behaviors and whether these self-reported metacognitive study strategies differentially related to learning. Although it is unclear whether these self-reports accurately reflect students' overt behaviors, they do reflect students' awareness of their perceived behaviors.

Given the constraints of self-reports, I focused on the constructive and active types of study strategies. I did not evaluate the interactive and passive strategies as these strategies were rarely described with enough detail to be accurately coded. For interactive strategies, students would need to work with others and incorporate each other's ideas. This level of engagement was not clear when students stated that they, "studied with a friend." Studying with a friend could entail interactive processes or could involve studying next to friends who are studying for other exams and not discussing the material. For passive strategies, students' reports were unclear as to whether some descriptions were related to passive or active strategies. For example, "I used the book" could mean "I searched the book for information" (active) or "I read the book" (passive).

In contrast, constructive and active activities were more clearly described by students. Study strategies were categorized as constructive if they required the generation of information and provided the opportunity to engage in sense-making processes (e.g., self-explanations, Aleven & Koedinger, 2002; Chi et al., 1994). Study strategies were categorized as active if they involved receiving and manipulating information (e.g., rewriting), but not generating or engaging in sense making. With the variety of study techniques reported in the literature (for reviews, see Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Karpicke et al., 2009; Koedinger, Booth, & Klahr, 2013; Richey & Nokes-Malach, 2015), I focused on a large subset of active and constructive strategies in order to compare whether students were engaging in different types of strategies and to evaluate whether these types of strategies were differentially related to learning outcomes.

Active strategies included: rewriting, highlighting, and summarizing. Constructive strategies included: generating examples, self-explaining, analogically comparing, and self-testing. I also included two additional constructive strategies that are not usually examined within student study strategies but are commonly evaluated within self-regulated learning research metacognitive monitoring and regulation (Winne & Perry, 2000; Zimmerman, 2008). Although monitoring is not usually included as a study strategy, it is often subsumed in other strategies (e.g., self-testing, Karpicke et al., 2009 and self-explanation, Aleven & Koedinger, 2002).

In the next few sections, I describe each of these strategies and their implications for learning. I ordered these strategies based on their relative benefit (low, high) for processing and learning the materials. *Low* ratings reflect processes that have shallow encoding in which the information is attended to and encoded, but the strategy does not require students to process that information further or integrate that information to prior knowledge. These strategies involve active engagement with the material. *High* ratings reflect processes that go beyond encoding and includes a level abstraction, integration, inference, revision, or retrieval of the concept. These strategies involve constructive engagement with the material and contain learning events as outlined by Koedinger and colleagues (Koedinger et al., 2013; Koedinger, Corbett, & Perfetti, 2012). These different ratings refer to the likelihood that they produce robust learning in comparison to other strategies. Robust learning is the process of acquiring robust knowledge that can be accurately applied to different situations, lasts over time, or enhances future learning in subsequent situations (Barnett & Ceci, 2002; Bransford & Schwartz, 1999; Koedinger et al., 2013, 2012). The degree to which these strategies go beyond the material allows for richer processing which has implications for how that knowledge might be transferred to later situations (Barnett & Ceci, 2002; Nokes-Malach & Mestre, 2013; Nokes, 2009). See Table 1 for an overview of how these different distinctions map to the processing strategies.

Table 1. *Strategies and their relative rating, relation to building robust knowledge, and the learning events they support.*

Strategy	Relative Rating	ICAP Category (Chi, 2009; Chi & Wylie, 2014)	Primary Learning Event (Koedinger et al., 2012, 2013)
Rewriting	Low	Active	N/A
Highlighting	Low	Active	N/A
Summarizing	Low	Active	N/A
Self-testing/Quizzing	High	Constructive	Memory, fluency-building
Analogically Comparing	High	Constructive	Induction, refinement
Generating examples	High	Constructive	Sense-making, understanding
Self-Explaining	High	Constructive	Sense-making, understanding
Metacognitive Monitoring	High	Constructive	Sense-making, understanding
Metacognitive regulation	High	Constructive	Sense-making, understanding

2.1.1 Rewriting

When students are asked how they study, a common response is that they rewrite their notes (Karpicke et al., 2009). Rewriting involves copying notes or information from the class (e.g., lecture slides, textbook, etc.). It is an active strategy that does not typically involve constructive processing of the information. It involves the rote rehearsal of information, which has been shown to be a less useful strategy than those that require elaborative encoding as it does not connect to prior knowledge or attempt to make the information more meaningful (Gardiner, Gawlik, & Richardson-Klavehn, 1994; Weinstein, Acee, & Jung, 2011). Rewriting may be more helpful if students use this strategy to organize the materials or integrate information from different sources. Given that rewriting does not involve generating information beyond the material or invite connections to prior knowledge, rewriting is hypothesized to have a low benefit to robust learning. Rewriting was coded for instances in which students mentioned rewriting the material from the course such as their notes, lecture notes, or the study guide. For example, students reported, “I rewrote notes that seemed to be the most challenging topics,” “I rewrote my notes onto flashcards,” and “I rewrote my notes to complete the study guide.”

2.1.2 Highlighting

Another common strategy students report using is highlighting material (Gurung, Weidert, & Jeske, 2010). Prior research on the benefits of highlighting on learning is mixed (for a review, see Yue, Storm, & Kornell, 2015). In some cases, highlighting may be a superficial way to processes the material if students are marking material without a purpose or are not sure which information to highlight (Dunlosky et al., 2013). In other cases, highlighting can aid in helping students more actively engage and attend to the highlighted information (Fowler & Barker, 1974). Similar to rewriting, highlighting does not typically go beyond the material or build from prior knowledge, resulting in a low benefit to robust learning. Highlighting was coded for instances in which students mentioned underlining, highlighting, starring, or circling information. For example, students reported, “I would highlight everything!!!,” “I would highlight to help remember difficult, or key concepts,” and “I would highlight the book.”

2.1.3 Summarizing

Summarizing involves stating the gist of the material. This encoding process has resulted in better performance than copying information (e.g., rewriting, Bretzing & Kulhavy, 1979). Other work has shown that summarizing can be more effective than rereading (Rewey, Dansereau, & Peel, 1991) but less effective than explaining (Bednall & James Kehoe, 2011). Summarizing has a low benefit to robust learning as it does not invite students to generate information beyond the material and does not connect to prior knowledge. Summarizing was coded for instances in which students mentioned that they summarized any of the materials such as the textbook, their notes, the lecture slides, or the study guide. For example, students reported, "I summarized chapters and sections of the textbook into my notes," and "I summarized notes from class."

2.1.4 Self-testing

Self-testing or quizzing is when students practice retrieving information from memory (for reviews see Rawson & Dunlosky, 2011; Roediger & Butler, 2011; Roediger, Putnam, & Smith, 2011; Roediger & Karpicke, 2006). Students have reported using self-testing as a way to monitor what they do and do not know (Kornell & Bjork, 2007), and self-reports of using self-testing have been positively related to GPA (Hartwig & Dunlosky, 2012). Although self-testing facilitates learning and builds fluency in the retrieval information, students believe that it is a less effective study strategy than merely active strategies such as rereading (Agarwal, Karpicke, Kang, Roediger, & McDermott, 2008; Karpicke et al., 2009; Kornell & Son, 2009; Roediger & Karpicke, 2006). One way to engage with self-testing is to use flash cards (Wissman et al., 2012); however, using flash cards has not been related to GPA (Hartwig & Dunlosky, 2012).

Therefore, I only examined self-testing if students stated that they quizzed or tested themselves. If students said they quizzed themselves with their flash cards, then they would be coded as using self-testing, but if they only mentioned they used flash cards, then they would not be coded as self-testing. With the benefits of generating information and retrieving information, self-testing has a high benefit to robust learning. Quizzing was coded for instances in which students mentioned testing or quizzing themselves. For example, students reported: "I would quiz myself on notecards that I made," "I would quiz myself on the sections of my notes," and "I would quiz myself on the in-class activities."

2.1.5 Analogically comparing

Analogical comparisons involve students identifying similar features between two concepts, examples, or cases (Gentner, 1983, 2002; Gentner & Colhoun, 2010). By comparing information, students engage in mapping, and inferences, resulting in a sense-making procedure that promotes understanding (for a review, see Alfieri et al., 2013). Using comparisons has helped students learn in a variety of contexts (Gentner & Namy, 1999; Kurtz, Miao, & Gentner, 2001). Some work has also shown that analogical comparison can promote students to engage in self-explanations (Edwards, Williams, & Lombrozo, 2013; Hoyos & Gentner, 2017; Richey, Zepeda, & Nokes-Malach, 2015). Although analogical comparison has been shown to promote transfer (e.g., Gick & Holyoak, 1983), some work has also shown that comparisons are sometimes less helpful than using explanations (Edwards et al., 2013; Richey et al., 2015). Analogical comparisons have a high benefit to robust learning as it invites the generation of knowledge beyond material and abstractions of the underlying features between the cases (Gentner, 2010; Holyoak, 2012). Analogical comparison was coded for instances in which students mentioned that they compared or contrasted the concepts/principles and for when students reported comparing the descriptions of concepts/principles from different resources from the course. For example, students reported: “Wrote out comparisons between theories,” and “compare and contrast concepts that were similar,” which were indicators that students compared concepts/principles. Others reported: “Reading over notes and finding examples in the book to compare class demos to” and “compared the material in the slides to the material in the book,” which were indicators that students compared information across the course materials.

2.1.6 Generating examples

Generating or creating examples involves connecting the concept to a situation or case. Creating examples invites students to build from their prior knowledge as they engage in inference generation and deductive reasoning, resulting in the refinement of their understanding. This process is similar to that of the generation effect in which students that are asked to generate part of the material perform better than those that read about the material (see Bertsch, Pesta, Wiscott, & McDaniel, 2007 for a review). Generating an example might also allow comparing to other examples, but that would acquire the use of additional strategies. For these reasons, generating examples has a high benefit to robust learning. Generating examples was coded for instances in which students mentioned that they created their own example(s). For example, students reported: “I would come up with examples to help understand the concepts and remember them,” and “Creating examples were a useful way to remember the concepts that we went over before each exam.” From these self-reports, it is unclear what “examples” mean, in some situations the examples might have involved more elaborations than examples such as the use of self-referencing.

2.1.7 Self-explaining

Self-explanations involve students explaining the material to themselves with the goal of making sense of the material (Richey & Nokes-Malach, 2015). Self-explaining can help students identify gaps in their understanding and revise errors and inconsistencies in their prior knowledge (Nokes et al., 2011). Prior work has shown the benefits of explanations on learning (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi et al., 1994; Hausmann & VanLehn, 2010). Self-explanations invite elaborating critical features of a concept, conditional knowledge about those features, and sense-making processes (Aleven & Koedinger, 2002). It also creates an opportunity for students to employ reasoning and inductions (Lombrozo, 2006, 2016). However, there are some constraints on when self-explanations benefit learning (e.g., it focuses students' attention to particular aspects and may draw attention away from other critical aspects; Rittle-Johnson & Loehr, 2017; Williams, Lombrozo, & Rehder, 2013). Given its connection to generating inferences, connecting to prior knowledge, and sense-making, self-explanation has a high benefit to robust learning. Self-explanations were coded was coded for instances in which students mentioned that they explained the concepts/topics to themselves. For example, students reported: “I tried explaining things to myself that were hard to comprehend,” “I would talk out loud or in my head to myself [about] the concepts,” and “I would try explaining and elaborating on concepts to myself.”

2.1.8 Metacognitive awareness

Metacognitive awareness involves students’ declarative knowledge that they monitor their understanding and regulate their approaches to improve their understanding (Schraw, 1998;

Schraw & Dennison, 1994). Monitoring one's understanding involves determining what one does and does not understand or know in which a learner identifies gaps in his or her knowledge. This process requires both awareness of one's knowledge and retrieval of information. Students often overestimate how much they know (Dunlosky, Hartwig, Rawson, & Lipko, 2011; Dunlosky & Lipko, 2007; Rawson et al., 2011); however, students who report being more aware of their understanding tend to have higher grades and GPA (Young & Fry, 2008). Although monitoring one's understanding has been described as a missing link or weakness in students' abilities to use other strategies effectively (e.g., self-testing, Karpicke et al., 2009), prior work has not examined whether students report monitoring their understanding. Students might view monitoring as an independent study strategy or as a component for describing other strategies. For example, when explaining principles or concepts students might have reported that they identified what they did not understand. Due to its use of retrieval and evaluation of prior knowledge, monitoring has high benefits to robust learning.

Metacognitive monitoring may help students identify gaps in their knowledge, but metacognitive regulation may go one step further and oversee the next steps to fill those gaps. Metacognition regulation involves controlling one's thoughts and action to adjust one's understanding (Nelson & Narens, 1990; Schraw & Dennison, 1994). Metacognitive regulation can also attune students to adjust their study strategies and prompts them to create a plan. Due to its use of retrieval, awareness of prior knowledge, and management of strategies, metacognitive awareness has high benefits to robust learning.

Both regulating and monitoring are central components of self-regulated learning (Pintrich, 2000; Winne & Hadwin, 1998), and past work has shown that high achieving students are more likely to monitor and regulate their learning (Isaacson & Fujita, 2006). Within questionnaires, metacognitive regulation and knowledge of one's cognitions (referred to as monitoring in this chapter) are often combined as one measure and are labeled as metacognitive awareness (Schraw & Dennison, 1994). However, EFAs and CFAs of the questionnaire measures (that are used in this chapter), revealed that these two factors were separable (see Appendix B). This separation of factors is consistent with theory (Flavell, 1979; Nelson & Narens, 1990; Pintrich, 2002) and verbal protocols or log data that separate metacognition into distinct factors (Greene & Azevedo, 2009; Meijer, Veenman, & van Hout-Wolters, 2006; Moos, 2014; van der Stel & Veenman, 2010). Additionally, during the initial creation of the open-ended coding protocol, metacognitive monitoring was the only aspect that was present (See Appendix A for the details on the development of the protocol). Therefore, we did not code for metacognitive regulation as a distinct strategy; although sometimes regulation was present in students' monitoring statements. Within the open-ended question, metacognitive monitoring was coded for instances in which students mentioned being aware or keeping track of their understanding or checking to see what they did or did not know. For example, students reported: "I was aware of what I did and didn't understand," and "During study sessions I briefly look over the study guide (that I created) and mark down what I think I understand and what I don't understand." Within some of these statements there was also some evidence of metacognitive regulation, such as "If I didn't understand something in my notes from lecture I would put it on my crib note," or "if I didn't understand something from the book I would try using the internet to gain a better understanding."

2.1.9 Summary

A student likely uses more than one of these study strategies when studying for an exam. For example, if a student identifies that she does not know what “bottom-up processing” this provides an opportunity for her to engage in other sense-making activities such as comparing bottom-up versus top-down processing, self-explaining what she thinks it means, or creating examples to illustrate the concept. These strategies may work together as described in the previous example or they could be used in isolation. A student may create an example for concepts A-B, but for concept C she explains to herself what the concept means. In this work, I examined whether students reported using these different study strategies for a set of exams, the consistency with which students reported using these study strategies, and how these study strategies related to exam performance.

2.2 RESOURCES – WHAT THEY USE TO STUDY

In addition to *how* students study I also examined *what* they studied. Students can choose to study materials provided by an instructor such as the lecture slides, the textbook, an outline, or a study guide. They can also go beyond what the class provides and choose to generate their own resources such as a concept map or flash cards. They might also search for information outside of the lecture such as using the internet or seeking help from others (e.g., studying with a group or attending office hours). Like study strategies, resources can require a different amount of effort and supply different benefits. For example, generating resources can take more effort and be more constructive than using a provided resource, but a provided resource might be more aligned with the test. Using resources can help fill in the gaps or clarify information, but resources may also be used in a superficial way. For example, students could glance through the study guide and identify what they think they know without actually retrieving information. Therefore, unlike the study strategies, I did not apply a distinction between resource effectiveness. Instead, I focused on how many resources students used and whether students changed the number of resources they used across the different exams. If students used several resources, then it might reflect that students put forth more effort as they integrated different types of information.

2.3 TIMING – WHEN THEY STUDY

The how and the what students study are two critical components in understanding students' metacognitive study strategies. A third component is *when* they study. Although students are aware that they should spend time studying, they typically do not view spacing out their studying as an aspect of studying (Wissman et al., 2012). Laboratory work has shown that increasing the amount of time students study (Vaughn & Rawson, 2011) and the number of sessions they study (i.e., distributed practice, Rawson & Dunlosky, 2011) results in long-term retention. Empirical work has been implemented in laboratory studies examining how these timing strategies benefit learning when used with retrieval practice (e.g., Kornell, 2009; Pashler, Zarow, & Triplett, 2003). Although this work has shown that timing can benefit student learning, student reports about their use of cramming (the opposite of spaced practice) and spacing studying sessions were not related to student GPA (Hartwig & Dunlosky, 2012). In this work, I examined the total amount of time students report they studied, the number of sessions they studied, and the amount of time they spend on different resources.

2.4 THE CURRENT STUDY

I examined students' metacognitive study strategies they reported using for three non-cumulative exams. The questionnaire included an open-ended question that asked students to describe their study techniques as well as Likert-scale and forced-choice questions about their use of study strategies, resources, and time management. Some of the study strategies were assessed by Likert-scale or forced-choice items to capture aspects of studying that might be more incidental or implicit to students such as monitoring understanding, using self-explanations, making analogical comparisons, and the spacing of studying. The questionnaire was framed to the context of each exam in which students were asked to state their studying techniques for the respective exam. In contrast, prior work which has captured students' general beliefs and values about study strategies (free of a course's context and the demands of a semester course load), the occurrence of the questions before each exam captured students' task-specific, retrospective judgments of how they studied. Additionally, this approach helped bridge the gap between the micro approaches of examining strategies within a task (e.g., Pashler et al., 2003), and the macro approaches of examining strategies at a general level (e.g., Hartwig & Dunlosky, 2012) by examining student perspectives within a class context.

I hypothesized that:

1. There would be a positive relation between exam scores and the use of constructive processing strategies, more time, and spaced study sessions. Further, these patterns would replicate across each exam.
2. There would be a subset of students that consistently used strategies and others that experiment and try out different strategies.
3. The corresponding constructs in the open-ended and Likert-scale measures would positively relate to each other.

2.5 METHOD

2.5.1 Participants

Approximately 395 undergraduates participated in the study as part of their normal completion of the course. Students received one extra credit point on their exams if they completed the survey before the exam. The Cognitive Psychology course is one of the University of Pittsburgh's Psychology Department's core courses and an Arts & Sciences general science requirement. Sixty-five students did not complete all the materials for the study, were missing demographic data or were outliers within the demographic data, resulting in a sample of 330 (242 females, 88 males) students. One-hundred and sixty-seven undergraduates were enrolled in a regular version of the course, and 163 were enrolled in a scaffolded version of the course. Using data from two courses allowed for a more generalizable investigation of the hypotheses. Students were approximately 20.49 years old, mostly female and white with a history of high performance (Table 2). See Table 2 for the sample's background characteristics.

Table 2. *Sample characteristics.*

Characteristic	*M* (*SD*) or Percentage
High-school GPA	3.91 (0.42)
Age	20.49 (1.21)
Psychology Major	70.29%
Female	73.20%
White	72.12%
Asian	17.58%
Black	2.73%
Hispanic/Latinx	0.30%
White and Asian	1.82%
Multiple Races with at least 1 Underrepresented Race/Ethnicity	5.45%

2.5.2 Measures

2.5.2.1 Questionnaire

The questionnaire asked students to describe how they studied for the exam. In addition to this open-ended question, students also responded to two yes/no questions, and several Likert-scale items assessing when students read, the amount of time they studied, how they allocated that time across different resources, and the number of study sessions they used. The questionnaire also assessed with a Likert-scale whether students kept track of what they knew (metacognitive monitoring, 2 items), whether they planned and regulated their studying (2 items, metacognitive regulation), self-explained the concepts (2 items), and compared the concepts (3 items). All of these items and their scales are presented in Table 3[1].

For the open-ended question that asked students to describe how they studied for each exam, I developed and applied a coding protocol (*N* = 990 responses, 330 for each exam). These codes captured how students processed the information which included: rewriting, highlighting,

[1] These items were from a larger questionnaire that also assessed students' motivations. A series of EFA and CFA explored and confirmed the structure of these items. Those results are presented in Appendix B.

summarizing, generating examples, explaining, comparing, monitoring, and quizzing themselves with the materials. Another set of codes also captured the resources students used which included: the notes, the book, sections of the book, study guide, internet, activities, practice exam, note card, group study sessions, and office hours. The reasoning behind coding for using the book versus book sections was to understand how students are using the book to study – were they using the book in general or were they using the book to reference specific information? Another set of codes aimed to capture how students spaced their studying which included studying throughout, a few days before, cramming the night before the test, and not studying at all. For each code the strategies were coded as present (1) or not present (0). Two coders reached reliability and coded these responses for the types strategies (kappa > .7). See Appendix A.1 for the more information about the development of the protocol, the protocol itself, and examples student responses.

Table 3. *Questionnaire items.*

Question Type	Construct	Item and Scale (if applicable)
Open-Ended	Multiple Strategies	In a paragraph or two, please describe your study techniques.
Yes or No	Multiple Strategies	Did you change your study techniques from exam 1 to exam 2?
	Resources - Working with others	Did you study with other students?
Likert-scale (1 = Never to 5 = Always)	Reading	How often did you read the assigned chapter BEFORE coming to class?
		How often did you read the assigned chapter AFTER coming to class?
Open-Ended	Time	How much total time did you spend studying in minutes for this EXAM (try to be as specific and as accurate as you can)?
Likert-scale (0, 25, 50, 75, 100)		What percentage of that time was spent reviewing the book?
		What percentage of that time was spent reviewing your lecture notes / slides?
		What percentage of that time was spent reviewing the study guide?
Likert-scale (1, 2, 3, 4, 5, 6 or more)	Spacing	How many study sessions did you have (regardless of length of time)?
Likert Scale (1 = Strongly disagree to 6 = Strongly agree)	Metacognitive Regulation	The first thing I did was think through a plan for what, when, and how to study.
		I kept track of my progress, and if necessary, I changed my study strategies.
	Metacognitive Monitoring	I knew when I understood a concept well.
		It was difficult for me to determine when I knew a concept well. (Rev)
	Self-Explanation	When I study, I pause to explain to myself difficult concepts so that I am sure I understand them.
		If I don't understand something, I stop to try to explain it to myself.
	Comparison	When I study, I compare and contrast different examples to one another.
		To better understand one concept, I compare it to another one.
		When studying class material, I compare and contrast different ideas to one another.

2.5.2.2 Exam scores

Both courses used the same three exams. The exams were not cumulative and consisted of 35 questions. The first exam covered the history and foundation, approaches and methods, perception, and attention. The second covered memory (working memory, short-term memory, long-term memory) and visual imagery. The third exam covered language, concepts, problem solving, expertise and creativity. Exam scores were calculated by taking the number correct and dividing it by 35 and multiplying the outcome by 100 to create a percentage.

2.5.3 Procedure

The instructors of the course distributed all of the survey materials via email three days before each exam (Figure 1). Within the questionnaire, students first responded to the Likert-scale, forced-choice, and open-ended questions about the amount of time they spent studying. Then they answered the open-ended question about their study techniques and then responded to the constructive strategies Likert-scale and a forced-choice question about changing strategies. All other questionnaire items were in randomized order. To receive extra credit, students had to respond to the surveys before the exam. The instructors of the course sent out reminders the morning of the exam to remind students to complete the survey if they wanted to receive the extra credit.

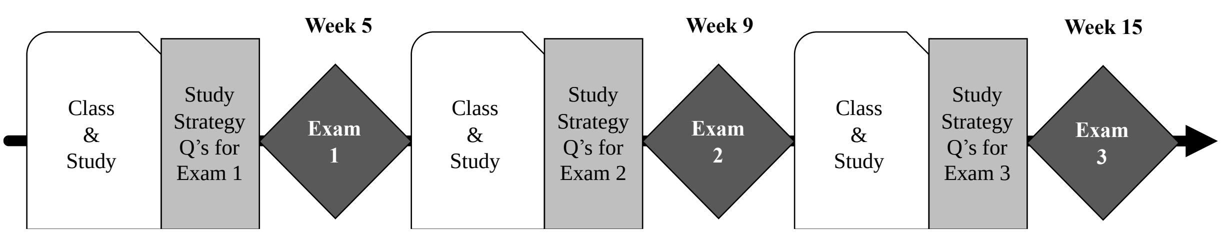


Figure 1. Study Design

2.6 RESULTS

The goal of this chapter was to examine the types of metacognitive study strategies students used in a college course. The first set of analyses examined the number and consistency in their reports of study strategies, resources, and time management. For the open-ended responses, consistency is reflected by: (1) the number of times students reported using the strategy across the three exams (mentioned for zero, one, two, or three exams), (2) the changes in these strategies from one exam to the next (exam 1 to 2, exam 2 to 3) and (3) the overall changes in strategies across the three exams (e.g., added at exam 3, removed at exam 2, consistently present). For the Likert-scale, consistency is reflected by a reliable change score (explained in more detail below). The second set of analyses examined students' responses to whether they changed their strategies. The third set examined the relation between the open-ended and Likert-scale items that measured the same strategies. The final set of analyses examined the relation of these metacognitive study strategies to exam performance. I set the alpha level at .05 and report relations for *p*-values less than .05 (Keppel & Wickens, 2004).

2.6.1 Number and consistency in study strategies, resources, and timing

For the open-ended question, I examined the number of study strategies, resources, and timing components that were mentioned in their responses. Within that text, students reported using an average of 1.33 study strategies, 3.18 resources, and 0.21 references to allocating their time across all the exams. Within study strategies, students reported an average of 0.34 active strategies and 1.00 constructive strategy across the exams. Due to the different number of possible strategies for active (3) versus constructive (5), the counts divided by the total number of possible strategies (3 for active, 5 for constructive). Students reported a proportionally similar amount of active and constructive strategies for the first exam (15% of active versus 22% of constructive, respectively). Then for the second and third exam, the proportional number of active strategies decreased whereas the constructive strategies were stable (exam 2: 9% of active versus 20% of constructive, respectively; exam 3: 15% of active versus 22% of constructive, respectively). Across all exams, students reported an average of 11% of the active strategies and 20% of the constructive strategies. The average counts for the study strategies, resources, and timing references are represented in Table 4.[2]

Table 4. *Counts for the number of study strategies, resources, and timing for each exam*

	Exam 1				Exam 2				Exam 3			
	M	*SD*	Min	Max	*M*	*SD*	Min	Max	*M*	*SD*	Min	Max
Strategies	1.56	1.17	0	5	1.29	1.15	0	6	1.15	1.08	0	4
Active	0.45	0.65	0	2	0.28	0.51	0	2	0.27	0.55	0	3
Constructive	1.11	0.92	0	4	1.01	0.96	0	4	0.88	0.82	0	3
Resources	3.56	1.25	0	9	3.07	1.14	0	6	2.92	1.13	0	7
Timing	0.19	0.39	0	1	0.12	0.34	0	2	0.33	0.51	0	2

2.6.1.1 Study strategies

Study strategies included rewriting, highlighting, summarizing, quizzing, analogically comparing, creating examples, self-explaining, and metacognitive monitoring. Figure 2, Panel A represents the percent of students that reported using a specific strategy for each exam[3]. In the open-ended question, students spontaneously reported that they monitored their understanding the most (62% of students, 57%, 52%, respectively for each exam), followed by quizzing themselves (28%, 16%, 14%, respectively for each exam) and rewriting information (26%, 11%,

[2] I also examined the number of words students wrote to describe their study techniques. These are presented in Appendix A.1.
[3] A table version of this data is presented in Appendix A.2.

12%, respectively for each exam). Students rarely reported summarizing (6%, 3%, 4%, respectively for each exam) and creating examples (5%, 4%, 4%, respectively for each exam).

Interestingly, the number of times students stated that they used a strategy across the exams varied (Figure 2, Panel B). Students' reports of using metacognitive monitoring had the largest variation whereas students' reports of summarizing had the least variation. In fact, monitoring was the only study strategy that the majority of students reported using for at least one exam. For the other strategies, most of the students did not report using them for any of the exams. Another approach to examining the variation in student use of the strategies is to examine when these strategies changed and how that changed occurred. Did a student add the strategy at exam 2 and then keep that strategy on exam 3? Or, did that student remove that strategy at exam 2 and then added it back to exam 3? These changes reflect a similar pattern as depicted in Figure 2, Panel B (see Appendix A.3).

When comparing constructive versus active strategy use across the exams (Figure 2, Panel A), the percent of students that reported using an active strategy decreased by exam 3. For constructive strategies, there was more variation. The percent of students that reported using some constructive strategies decreased (e.g., quizzing) whereas there were other strategies in which the percent of students increased (e.g., self-explaining) across the exams. When examining the frequency with which a student reported using a strategy across the exams (Figure 2, Panel B), the majority of students did not report using an active strategy whereas there was more variation for the constructive strategies. Across the exams, more students were trying out or consistently using a constructive strategy, particularly in their reported use of quizzing and monitoring.

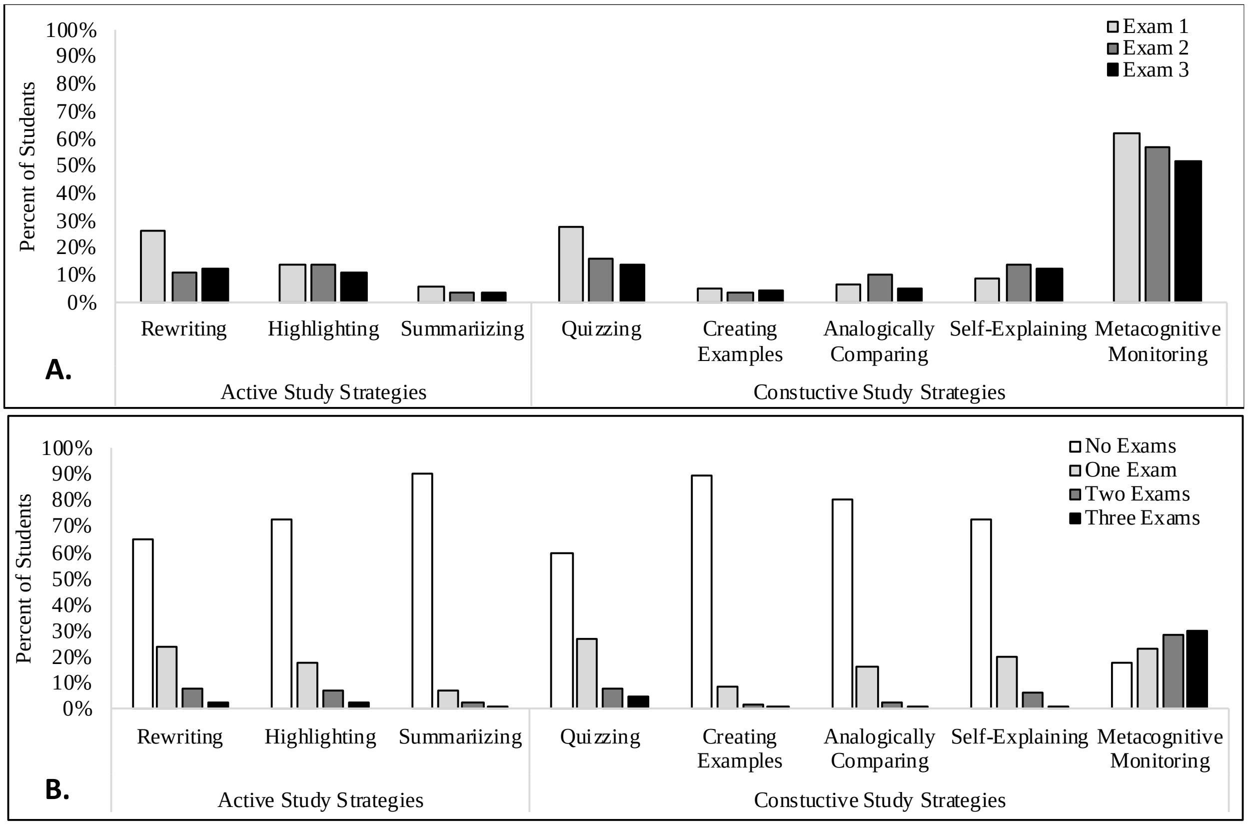


Figure 2. Percent of students who reported using each study strategy by exam (A) and the consistency in the number of times a student stated a study strategy (B).

The Likert-scale items revealed that students thought they used a moderate amount of metacognitive regulating, metacognitive monitoring, self-explaining, and analogically comparing (Table 5). These responses were fairly consistent across each exam transition. Using the Reliability Change Index (RCI; Bauer, Lambert, & Nielsen, 2004; Christensen & Mendoza, 1986; Jacobson & Truax, 1991), I examined whether students maintained their responses across exams. The RCI determines whether student responses to a measure is due to actual changes in student responses to the construct between observations and not to noise in the measurement. This reliable change score is calculated by taking the difference in time 1 and time 2 means and dividing that difference by the difference in the standard error of the difference between the two scores. The resulting RCI scores are used to categorize students that increased (scores above

1.96), decreased (scores below -1.96), or maintained their responses between the two time points (scores between -1.96 and 1.96).

For metacognitive monitoring, 39 (12%) students reliably changed their response between exam 1 and 2 and 33 (10%) reliably changed their response between exam 2 and 3. For metacognitive regulation students were fairly consistent; 45 (14%) and 37 (11%) students reliably changed their response between exam 1 and 2 and between exam 2 and 3, respectively. More change occurred for self-explanation and analogical comparison. For self-explanation, 96 (29%) and 107 (32%) students reliably changed their response for the first and second exam transition, respectively. For analogical comparison, 106 (32%) and 95 (29%) reliably changed their response for the first and second exam transition, respectively. Students that did change their reported use of the strategy could have either increased or decreased their reported use (see Figure 3). These results showed that a small subset of students naturally changed the strategies they employed between exams with more variation occurring for self-explanation and analogical comparison and less variation for strategies that required students to engage in metacognitive monitoring or regulation.

Table 5. *Descriptive statistics for the processing Likert-scale items.*

Exam		Metacognitive Monitoring	Metacognitive Regulation	Self-Explanation	Analogical Comparison
Exam 1	*M*	4.41	4.14	4.77	4.28
	SD	0.89	0.98	0.83	0.88
	Min	1	1.5	1	1.67
	Max	6	6	6	6
Exam 2	*M*	4.39	4.13	4.77	4.26
	SD	0.78	0.98	0.83	0.81
	Min	2	1	2	1.67
	Max	6	6	6	6
Exam 3	*M*	4.42	4.38	4.88	4.36
	SD	0.79	0.89	0.79	0.79
	Min	1.50	2	2	1.67
	Max	6	6	6	6

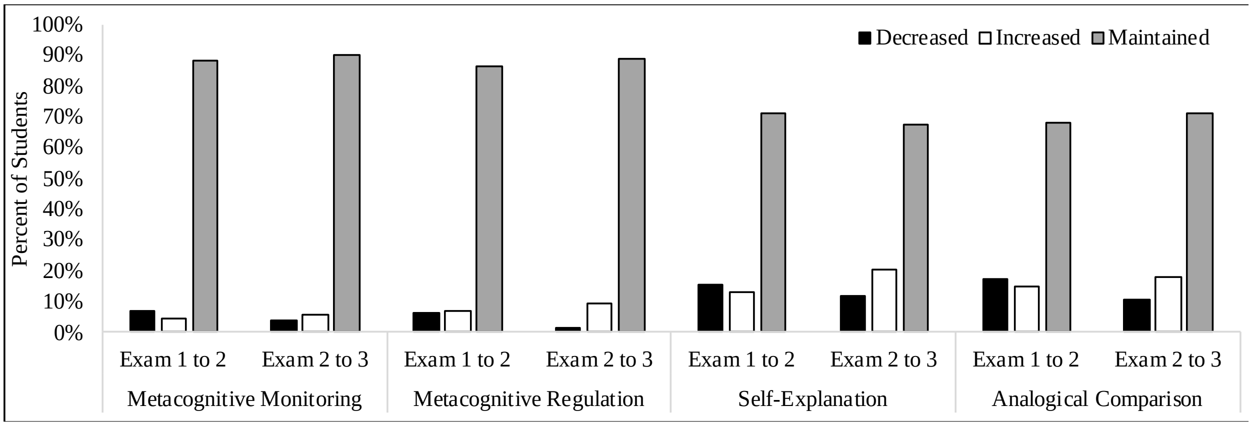


*Figure 3.*Consistency in the percent of students who increased, decreased, or maintained their endorsements as indicated by the RCI for the Likert-scale strategies between each exam transition

In addition to whether they changed between one transition to the next, I also examined whether they changed across both exam transitions or not at all. The reasoning behind this investigation was to evaluate how much students try out different strategies. The majority of students maintained their use of the metacognitive components: 270 (82%) of students maintained their use of metacognitive monitoring and 259 (78%) of students maintained their use metacognitive regulation. Approximately half of the students maintained their use self-explanation (176 students, 53%) and analogical comparison (174 students 53%). Again, these results showed that students did not change their metacognitive behaviors as much as their self-explanation or analogical comparison strategies. For the students that did not maintain their strategy use, they could have experienced different changes in their use of the strategies. They could have increased and then decreased, maintained and then decreased, decreased and maintained, and so forth. See Appendix A.4 for these results.

2.6.1.2 Resources

Resources involved the types of materials students used while studying. Resources included: notes, book section, entire book, study guide, activities, practice test (just for exam one), note card (an allowed note card they could use during the exam), created their own resource, used the internet, worked with others, and attended office hours. The most common resource was using/reviewing/reading notes, and the least common was attending office hours (Figure 4, Panel A). More students used the provided resources than using resources they had to source themselves (e.g., creating a resource, using the internet, working in a group or attending office hours). Students were most consistent in stating that they were using/reviewing/reading their notes and the study guide (Figure 4, Panel B). When asked if students worked with others, approximately twice as many students responded that they studied with others to the yes/no question than they did in the open-ended question (compare 52 to 105 for exam 1, 57 to 111 for exam 2, 54 to 107 for exam 3).

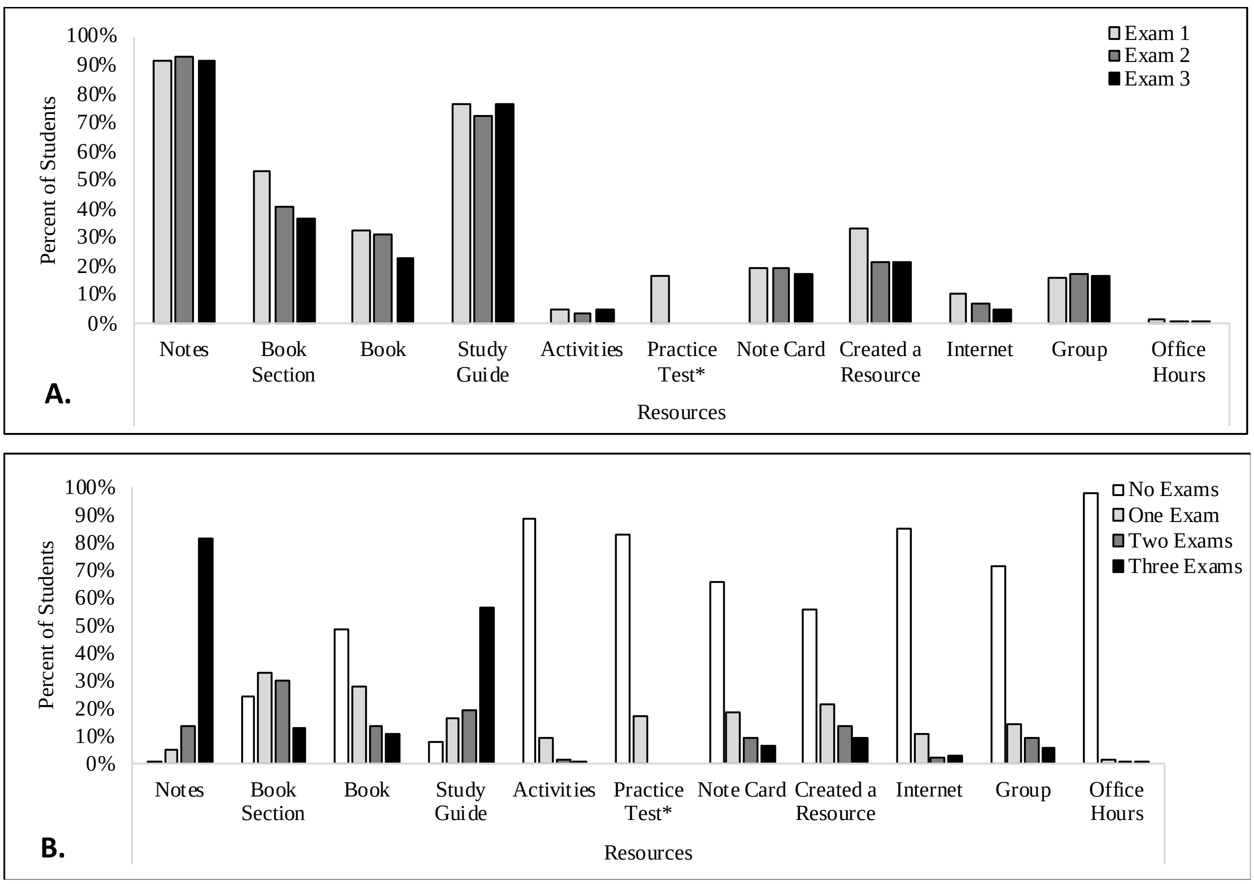


Figure 4. Percent of students who reported using each resource by exam (A) and the consistency in the number of times a student stated a resource (B).

2.6.1.3 Time management

A handful of students mentioned timing in their open-ended responses (Figure 5). Averaging across the exams, 6% of students mentioned they studied throughout to prepare for the exam, 7% stated they studied a few days before and 1% stated they crammed the night before. No students said they did not study. When examining students' consistency in mentioning they spaced their studying (regardless of length), only 29% of students referenced timing during one exam or another.

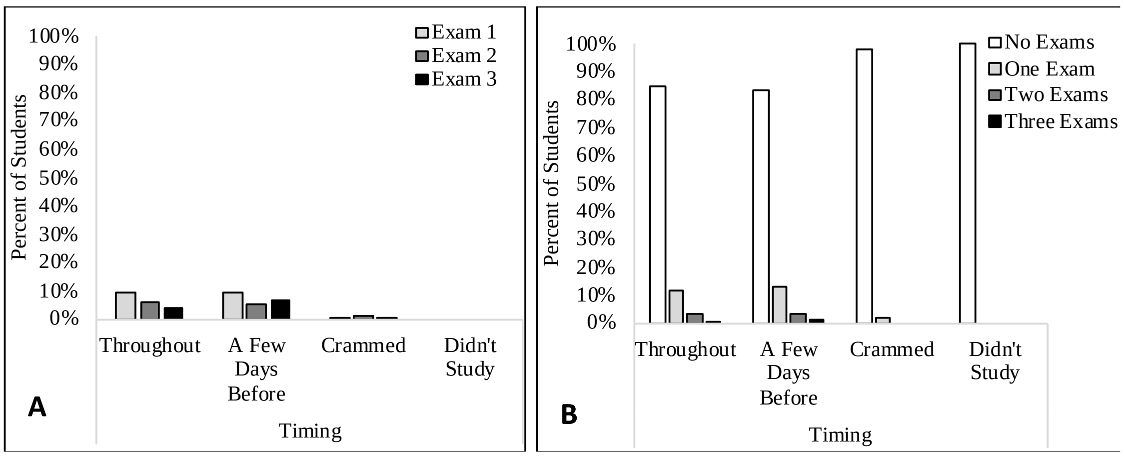


Figure 5. Percent of students who reported using each time management category by exam (A) and the consistency in the number of times a student stated a time management category (B).

Descriptive statistics for student responses to the forced-choice and Likert-scale time questions are in Table 6. On average, students sometimes read the book before the class and sometimes read the book after class. When students were asked to enter the amount of time they studied (in minutes) some students responded with data that were not translatable into minutes (e.g., "maybe four days," "few hours a day") and were therefore not included in the time analyses. Across the exams, students averaged studying for 366.20 minutes (6 hours and 6 minutes; *SD* = 317.74), and there was minimal variation across the exams (Table 6). Within that time, students reported spending the majority of their time reviewing the lecture notes/slides. Students also did not space out their studying across the semester as they averaged with three and half study sessions across the exams. Again, there was little variation across the exams in the number of study sessions students reported.

Table 6. *Responses to prompting questions.*

		Read the Book			Percent of that Time Reviewing			
		Before	After	Time Studying	The Book	The Lecture Notes/Slides	The Study Guide	Number of Study Sessions
Scale		Never (1) to Always (5)	Never (1) to Always (5)	Minutes		0, 25, 50, 75, 100		1 2 3 4 5 6 or more
Exam 1	*M*	2.71	2.85	361.25 (*N*=329)	26.59%	56.14%	45.53%	3.56
	SD	1.23	1.22	302.10	17.63%	21.49%	27.02%	1.41
	Min	1	1	0	0%	25%	0%	1
	Max	5	5	3600	100%	100%	100%	7
Exam 2	*M*	2.33	2.90	331.05 (*N*=327)	26.44%	55.45%	43.79%	3.54
	SD	1.15	1.24	212.85	18.07%	21.72%	27%	1.42
	Min	1	1	2	0%	0%	0%	1
	Max	5	5	1440	100%	100%	100%	7
Exam 3	*M*	2.15	2.68	406.22 (*N*=328)	21.06%	60.15%	43.03%	3.66
	SD	1.12	1.21	404.12	17.31%	21.60%	28.12%	1.49
	Min	1	1	4	0%	0%	0%	1
	Max	5	5	4800	100%	100%	100%	7

2.6.1.4 Global strategy change

Students also rated whether they changed their strategies between each exam transition (exam 1 to 2; exam 2 to 3). For the first transition, 187 students reported that they did not change their study strategy approach, and 143 students reported that they did. For the second transition, 211 students said they did not change their study strategy approach, and 119 said they did. Across both transitions, 61 students (18%) reported that they changed their study strategy approach, 140 students (42%) reported that they changed their study strategy approach for one exam, and 129 students (39%) reported that they did not change their study strategy approach. This result reflects that students are adapting their strategies, which may be on purpose or due to contextual constraints (e.g., during midterm season there may be more time demands, during final exams there may be more on the line to perform well).

2.6.2 Relation between open-ended and Likert-scale items

Three of the study strategies were measured by both open-ended and Likert-scale items: metacognitive monitoring, self-explanation, and comparison. To evaluate whether these two types of measures were aligned across the three strategies, I used Kendall's Tau partial correlations with student sex, race/ethnicity, age, high school GPA, and class entered as covariates with the ppcor package in R in to reflect the dichotomy in the variables and the non-normality (Kim, 2015). This approach removed the variance explained by student sex, race/ethnicity, age, high school GPA, and the class they were enrolled in. Sex (male = 0, female = 1), race/ethnicity (represented majority = 0, underrepresented minority = 1), and class (typical course = 0, scaffolded course = 1) were dichotomously coded. High school GPA and age were included as continuous variables. Students' open-ended responses were also coded dichotomously (strategy present = 1, not present = 0) and their responses to the Likert-scale measures were coded as continuous.

The correlations between the statements and their respective Likert-scale measures are presented in Table 7. On the first exam, each strategy statement was positively related to their respective Likert-scale measure. If a student said they used that strategy in the open-ended question, then they also rated themselves higher on the matching Likert-scale. On the second and third exams, each strategy statement was positively related to their respective Likert-scale measure with the exception of the metacognitive strategy. Students who said they checked their understanding did not rate themselves higher on the metacognitive regulation or metacognitive personal knowledge Likert-scale measures for exam 2. For exam 3, students who said they checked their understanding did not rate themselves higher on the metacognitive regulation Likert-scale measures. This result suggests that metacognition might be a difficult construct to adequately measure.

Table 7. *Kendall's Tau partial correlations between the Likert-scale measures and their respective open-ended measure*

	Exam 1 Statement		Exam 2 Statement		Exam 3 Statement	
Likert-scale measure	r_t	*p*-value	r_t	*p*-value	r_t	*p*-value
Metacognitive Monitoring	.10	.007	.05	.16	.11	.003
Explanation	.20	<.001	.17	<.001	.13	<.001
Comparison	.08	.03	.11	.003	.16	<.001

2.6.3 Relation to exam performance

Identifying which strategies students are aware that they used to study for each exam provides insight into whether these strategies are used in a college context. However, it does not reveal whether students who performed better on exams were employing certain types of strategies. To answer this question, I examined the partial correlations between student exam performance and their strategy use. For all analyses examining the relation to exam performance, I used Kendall Tau's partial correlations with the ppcor package in R (Kim, 2015) to remove the variance explained by student sex, race/ethnicity, age, high school GPA, and the class they were enrolled in to reflect the dichotomy in the variables and the non-normality. Some of these correlations are presented in a graphical form which was derived from the corrplot package in R (Friendly, 2002; Murdoch & Chow, 1996).

For each of the exams, there were two outliers, and therefore their data were excluded from these analyses. The same pattern of results appeared when including the outliers. Across all three exam students scored on average in the B- to B ranges (Exam 1: $M = 83.42$, $SD = 8.31$; Exam 2: $M = 82.32$, $SD = 9.93$; Exam 3: $M = 84.14$, $SD = 8.84$). Given the lower mean of exam 2, I examined whether there was a within-subjects difference between exam 2 and the other two exams with a multilevel model that predicted exam performance by exam (1, 2, 3). The model included the random intercepts of high school GPA, age, gender, underrepresented minority status, course, and students within a course. All continuous variables were centered, and effects coding was applied so that exam 2 was the reference category. The model revealed that there were within differences on exam performance, $F(2,650) = 6.72$, $p = .001$, $R^2 = .67$). Exam 2 was harder than exam 1 ($B = 1.10$, $SE = 0.50$, $\beta = 0.05$, $SE(\beta) = 0.03$, $p = .03$) and exam 3 ($B = 1.81$, $SE = 0.50$, $\beta = 0.09$, $SE(\beta) = 0.26$, $p < .001$).

2.6.3.1 Open-ended

To identify whether there were relations between students' self-reported strategies and exam performance, I applied the same analytical approach in which I used Kendall Tau's partial correlations to remove the variance explained by student sex, race/ethnicity, age, high school GPA, and the class they were enrolled in. Students' open-ended responses were coded dichotomously (strategy present = 1, not present = 0). Graphical representations of these correlations are represented in Figure 6. These relations are described below.

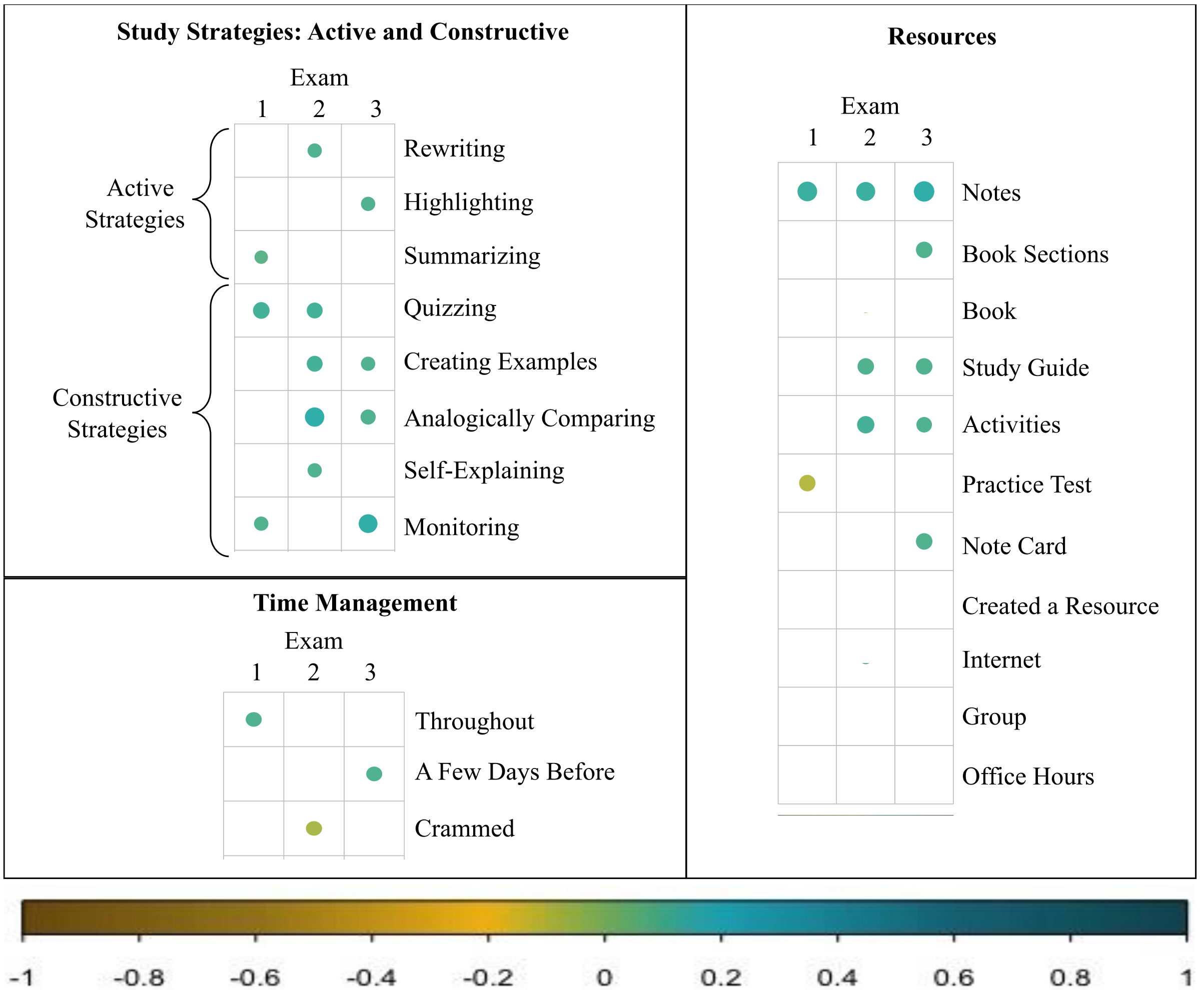


Figure 6. Corrplot of the correlations between exam performance and the open-ended questionnaire. All circles represent $p < .05$. The heat map represents the r-value.

Study Strategies

For the first exam, there were small positive relations between students' exam performance and stating that they summarized (r_t = .07, p = .048), quizzed themselves (r_t = .11, p = .003), monitored their understanding (r_t = .08, p = .04). For the second exam, there were small positive relations between students' exam performance and stating that they rewrote materials (r_t = .08, p = .04), quizzed themselves (r_t = .10, p = .007), generated examples (r_t = .10, p = .006), analogically compared (r_t = .15, p < .001), used self-explanations (r_t = .08, p = .03). For the third exam, there were small positive relations between students' exam performance and stating that they highlighted (r_t = .08, p = .03), generated examples (r_t = .08, p = .03), analogically compared (r_t = .09, p = .02), monitored their understanding (r_t = .14, p < .001). From these relations, it is evident that more of the constructive strategies were positively related to exam performance than the active strategies, even when taking into account the disproportional number of active (3/9 = 33% of the strategies were related to exam performance) versus constructive strategies (9/15 = 60% of strategies were related to exam performance).

Resources

For the first exam, there were small positive relations between students' exam performance and stating that they used their notes (r_t = .13, p < .001). There was a small negative relation between exam 1 performance and if students stated that they used the practice test (r_t = -.09, p = .01). For the second exam, there were small positive relations between students' exam performance and stating that they used their notes (r_t = .12, p < .001), the study guide (r_t = .09, p = .01) and the activities (r_t = .10, p = .006). For the third exam, there were small positive relations between students' exam performance and stating that they used the note card (r_t = .09, p = .01), their notes (r_t = .14, p < .001), sections of the book (r_t = .01, p = .02), and the activities (r_t = .08, p = .04).

Timing

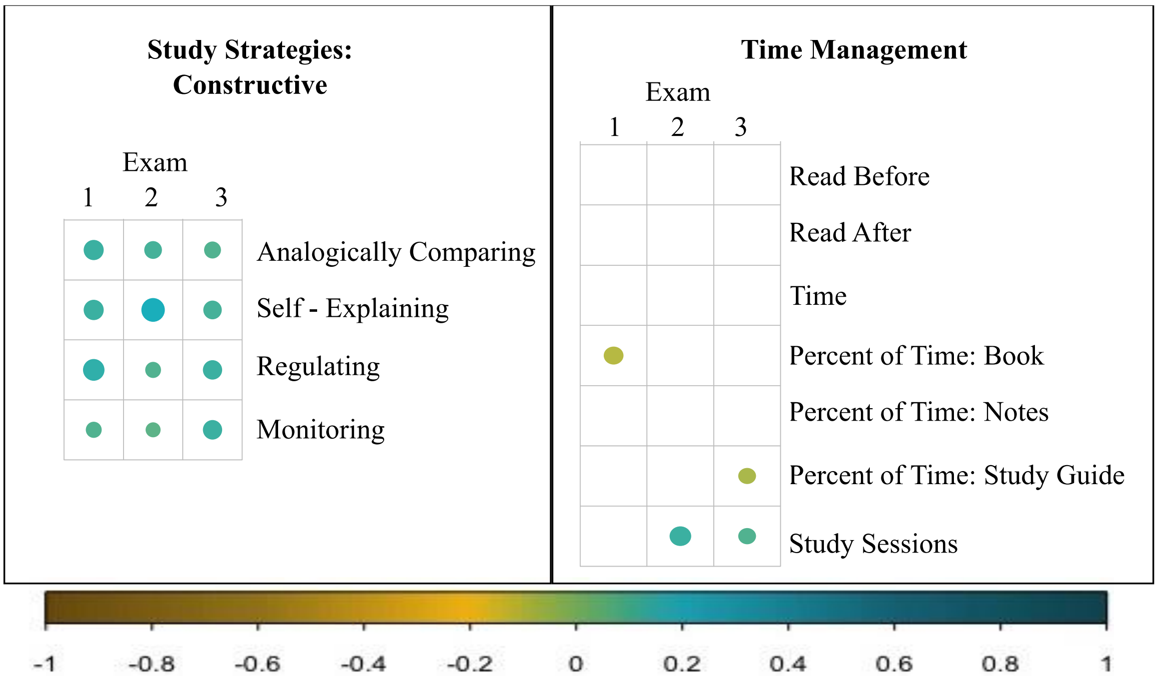
For the first exam, there was a small positive correlation between students' exam performance and stating they studied throughout (r_t = .08, p = .03). For exam 2, there was a small negative relation between exam 2 performance and if students stated that they crammed (r_t = -.08, p = .03). For the third exam, there were small positive relations between students' exam performance and stating that they studied a few days before the exam (r_t = .08, p = .03). These results are consistent with prior work that finds spacing out studying results in better learning outcomes.

Number of strategies, resources, timing references

For any given exam, students could have stated using multiple strategies, resources, or timing references (see Table 4). Perhaps if students used more strategies, then they would perform better on the exam. For each exam, there was a positive relation between exam performance and the number of constructive strategies (Exam 1: $r_t = .09$, $p = .02$, Exam 2: $r_t = .15$, $p < .001$, Exam 3: $r_t = .16$, $p < .001$). The number of active strategies was only related to exam 2 performance (Exam 1: $r_t = .04$, $p = .32$, Exam 2: $r_t = .09$, $p = .02$; Exam 3: $r_t = .07$, $p = .07$). The number of resources were not related to exam 1 performance ($r_t = .02$, $p = .59$), but there was a small positive relation to exam 2 ($r_t = .09$, $p = .02$) and exam 3 performance ($r_t = .14$, $p < .001$). The number of time references was positively related to exam 1 performance ($r_t = .09$, $p = .01$), but not to exam 2 ($r_t = .02$, $p = .68$), or exam 3 ($r_t = .05$, $p = .17$).

2.6.3.2 Likert-scale

For the Likert-scale measures, I used the same analytical approach with the use of Kendall's Tau partial correlations and using student sex, race/ethnicity, age, high school GPA, and the class they were enrolled in as covariates (Figure 7). The constructive strategies were consistently related to exam performance. For the first exam, there were small positive relations between students' exam performance and the amount they reported using self-explanations ($r_t = .13$, $p < .001$), analogical comparisons ($r_t = .13$, $p < .001$), metacognitive regulation ($r_t = .15$, $p < .001$), and metacognitive monitoring ($r_t = .08$, $p = .03$). For the second exam, there were small positive relations between students' exam performance and the amount they reported using self-explanations ($r_t = .18$, $p < .001$), analogical comparisons ($r_t = .10$, $p = .009$), metacognitive regulation ($r_t = .08$, $p = .02$), and metacognitive monitoring ($r_t = .07$, $p = .049$). For the third exam, there were small positive relations between students' exam performance and the amount they reported using self-explanations (r_t = .11, p = .005), analogical comparisons (r_t = .09, p = .02), metacognitive regulation (r_t = .12, p = .002), and metacognitive monitoring (r_t = .12, p = .001).



Note. All circles represent $p < .05$. The heat map represents the *r*-value.
Figure 7. Corrplot of the correlations between exam performance and the Likert-scale questions.

For time management, there was more variation in its relation to exam performance. For exam 1, there was a small negative relation between exam performance and the percent of time students reported reviewing the book (r_t = -.10, p = .01). There was also a negative relation between the percent of time reviewing the study guide and exam 3 performance (r_t = -.08, p = .04). There were two positive relations such that students with higher performance on exam 2 and 3 reported using more study sessions (r_t = .12, p = .002; r_t = .08, p = .04, respectively).

2.6.4 Yes-no questions: studying with others and changing strategies

Kendall's Tau partial correlations were applied to examine the relation between students reporting that they studied with others and changed their strategies with exam performance. Studying with others was not related to exam 1 (r_t = .05, p = .21). Studying with others was positively related to exam 2 performance (r_t = .08, p = .03) and negatively related to exam 3 performance (r_t = -.09, p = .01).

There was a small negative relation between changing strategies and exam 2 performance (r_t = -.10, p = .003) and no relation for exam 3 (r_t = -.05, p = .12). Given that changing one's strategies might be dictated by prior exam performance, one multilevel model was applied to each exam transition in which change in study strategies (no/yes), prior exam performance, and their interaction were regressed on current exam performance. Random intercepts of sex, race/ethnicity, age, high school GPA, and class were included in the model to account for those variances. Effects coding was applied to change in study strategies (-.5, .5) and the exam scores were entered as percentages. The models were run in with the lme4 (Bates, Mächler, Bolker, & Walker, 2015) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017) packages in R and were modeled with the effect package in R (Fox, 2003). The model for exam 2 revealed that changing strategies was not related to exam 2 performance, holding all else constant (Table 8). Prior exam performance was positively related to exam 2 performance, holding all else constant. There was no interaction between prior exam performance and changing strategies. The model for exam 3 revealed a different pattern (Table 8). There was an interaction between changing strategies and prior exam performance such that students who performed poorly on the prior exam and did not change their strategies performed lower on exam 3 than students that also performed lower on the prior exam but changed their strategies (Figure 8).

Table 8. *Output for multilevel models predicting the current exam performance by prior exam score and whether students reported generally changing their strategies*

Exam	Variable	Estimate	*SE*	β	*SE*(β)	*df*	*t*-value	*p*-value	R^2
Exam 2 (*N*=327)	(Intercept)	24.59	5.19	0	0	313.80	4.74	<.001	.44
	Changed Strategy	8.92	10.24	0.44	0.51	322.00	0.87	.38	
	Didn't Change Strategy	Ref.							
	Exam 1 Percent	0.69	0.06	0.57	0.05	315.00	10.93	<.001	
	Exam 1 Percent: Changed Strategy	-0.08	0.12	-0.32	0.51	321.80	-0.62	.53	
Exam 3 (*N*=327)	(Intercept)	48.64	3.85	0	0	127.20	12.63	<.001	.26
	Changed Strategy	19.63	7.49	1.07	0.41	316.60	2.62	.01	
	Didn't Change Strategy	Ref.							
	Exam 2 Percent	0.43	0.05	0.48	0.05	147.00	9.29	<.001	
	Exam 2 Percent: Changed Strategy	-0.22	0.09	-0.99	0.41	318.60	-2.43	.02	

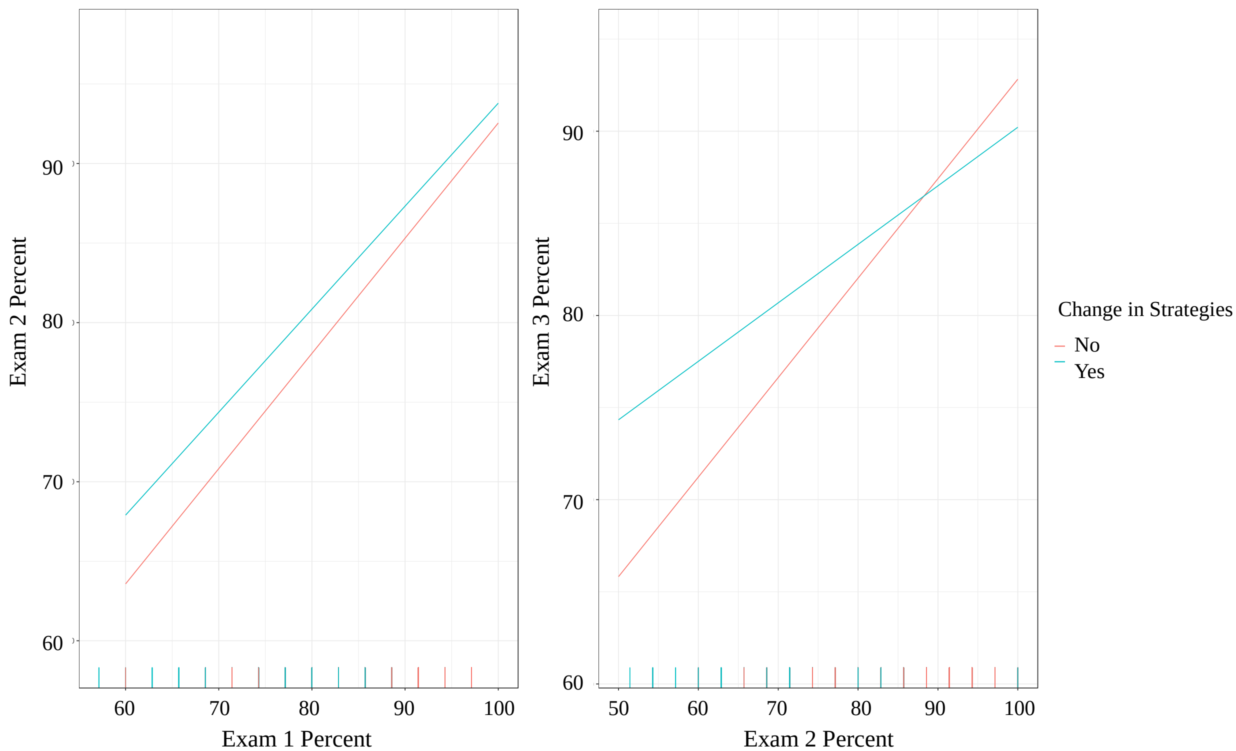


Figure 8. Graphical representation of the interaction between prior exam performance forced-choice response to changing strategies. The shaded bands reflect the confidence intervals.

2.7 DISCUSSION

The purpose of this chapter was to explore which types of strategies students reported using and how those strategies related to exam performance. Critically, to obtain a broad view of student metacognitive study strategies, I integrated different strands of prior work examining student study strategies and instructional techniques. From this process, three approaches to studying emerged: the use of study strategies, resources, and time management. To assess these aspects of studying, students responded to different types of measures (open-ended, Likert-scale, forced-choice). Each type of measure had different affordances. The use of the open-ended question provided a census about which study approaches were most salient to students as their responses were spontaneous and self-generated. In contrast, the use of the Likert-scale and forced-choice questions required students to make judgments about prompted strategies. Across the measures, students reported using several different types of strategies, and although the types of strategies varied, students were fairly consistent in their use of *most* strategies across the exams. In the next few sections, I discuss each of the strategy types, their relation to exam performance, and the relations across measures. Then I discuss some limitations and directions for future work.

2.7.1 Study strategies

Study strategies involved how students worked through the information in the course. These included: rewriting, highlighting, summarizing, generating examples, self-explaining, analogically comparing, self-testing, metacognitive monitoring, and metacognitive regulation. Aligned with the ICAP framework (Chi, 2009; Chi & Wylie, 2014) these strategies were categorized to represent different levels of engagement from students: active and constructive engagement. Although this work was not able to capture the overt behaviors of students (a fundamental assumption in the ICAP hypothesis), this work was able to capture students' reports of their overt behaviors. As indicated by the literature review, each of these strategies sometimes has produced learning benefits, but this relation depends on the way students use the strategy. The findings from this work generally support the ICAP hypothesis as more of the constructive strategies were positively related to exam performance than the active strategies.

The constructive strategies included: generating examples, quizzing, metacognitive monitoring, metacognitive regulation, self-explaining, and analogically comparing. The latter four were measured with both the open-ended and Likert-scale questions. In the open-ended responses, students reported monitoring their understanding the most. This strategy also had the most variation in that students fluctuated using this strategy across the exams. Although prior work has found that students often overestimate what they know (Dunlosky et al., 2011; Dunlosky & Lipko, 2007; Rawson et al., 2011), students that reported monitoring their understanding also performed better on the first and third exam, suggesting that students were able to keep track of what they did and did not know to some extent. Students' Likert-scale responses to monitoring their understanding and regulating their learning processes were also related to exam performance. These relations are consistent with prior work on self-regulated learning (Isaacson & Fujita, 2006; Kornell & Metcalfe, 2006; Rawson et al., 2011) in that students who monitor and control their learning processes are likely to perform well.

Quizzing was the second most reported and was related to performance on the first two exams. This finding is consistent with prior laboratory work (Roediger & Butler, 2011; Roediger & Karpicke, 2006) and with Hartwig and Dunlosky (2012) that found a positive link between students' self-reported use of quizzing and GPA. Fewer students reported quizzing on exam 3, so perhaps that is why there was no relation. Although generating examples was the least common constructive strategy, it was positively related to exam 2 and exam 3. When creating examples, students might be creating stronger connections and a deeper understanding of the different principles, which allowed them to apply their knowledge to the exams more accurately.

Although prior work examining study strategies has not examined student use of self-explanations and analogical comparison, students also reported comparing and explaining information to themselves in both the open-ended and Likert-scale questions. The Likert-scale responses for these constructs were related to exam performance for all three exams. That was not the case for the open-ended. The open-ended responses for self-explanations were only related to exam 2 whereas analogical comparison was related to exam 2 and exam 3. One explanation for this result is that exam 2 was more difficult than the other two exams and required students to have a more in-depth understanding of the material. Perhaps because of this change in exam difficulty, students who were explicitly aware that they used self-explanation and analogical comparison had the chance to demonstrate their knowledge. Another explanation is that students were learning how to apply those strategies within their own studying. Throughout the semester, a subset of students changed their Likert-scale responses (as indicated by the RCI) in using self-explanation and analogical comparison strategies across the semester. This change may have been a natural progression as students were learning how to use and apply these strategies.

The remaining three strategies were active strategies: rewriting, highlighting, and summarizing. These items were only examined with the open-ended question. Few students reported summarizing, but those that did on exam 1 also performed better on that exam. Rewriting and highlighting are historically a common strategy to report; however that pattern did not appear in the student responses to the open-ended question. Highlighting was related to performance on the third exam which is consistent with some work demonstrating that when used correctly highlighting can be productive (Wissman et al., 2012). Students who reported rewriting for exam 2 also performed better on that exam. This relation might have depended on the way students were rewriting information. Perhaps students who reported rewriting on the second exam did so in a more organized way which allowed them to make connections with the material or integrate the different materials.

2.7.2 Resources

Prior work rarely examined the types of resources students report using to aid in their studying. One reason prior work might not have examined the types of resources could be because the types and number of resources vary across different courses. In the open-ended responses, students reported using resources more than study strategies or time management. For students, the physical resources seem to be more salient than those that are not in plain view (e.g., thoughts in one's head, time). Studying is about some topic, so although students may have used one or two main study strategies (e.g., monitoring understanding and quizzing) those strategies are used with certain materials. Thus, the materials might have been more salient as there are several resources within a course.

The majority of students consistently used their notes, but rarely used the activities that were used in the lecture, the practice test, office hours, or the internet. There was a large variation in their use of the book, the study guide, and creating resources. The use of the note cards had some variation. Perhaps because of these variations, the relations between resources and exam performance varied. Notes were positively related to exam performance for each exam, and it was a consistently present response. In contrast, the study guide was consistently reported to be used by about half of the students, and the majority of students reported using the study guide at one time or another. The study guide was related to performance on exam 2 and 3 performance, which might have been due to students recognizing how closely the study guide related to the material on the exams based on their experience with exam 1. Activities were rarely used, but at exam 2 and 3, they were positively related to exam performance. One explanation for this finding is that, after the first exam, students began to realize the importance of the activities presented in the lecture materials. Although students rarely used the note card, at exam 3 the mentioning of note cards was positively related to exam performance. At exam 3, students have their last chance of boosting their grade while also managing their other course grades, so perhaps students were using whichever resources they could to give them that extra edge.

In addition to the open-ended question, students also responded to a forced-choice question about working in a group. For the open-ended responses there was no relation to exam performance, but for the forced-choice question, the relations were mixed. For the first exam, there was no relation between the forced-choice and exam performance, but for the second exam there was a positive relation, and for the third exam there was a negative relation. At the end of the semester, students leave campus for the holidays or summer, which might lead students to socialize more than study during group work. They might be more likely to discuss their plans for break or generally socialize, knowing that they may not see their peers over the break, resulting in less time for studying. The results are somewhat consistent with Hartwig and Dunlosky's (2012) finding in which they found a negative association between studying with friends and GPA. Specific to the context of these courses, one reason for these conflicting findings might be that students engaged in group work during lecture and outside of class. The inclusion of collaborative activities might have allowed students to engage in productive collaboration with classmates, but then, as the semester finished, their collaborations became more of a social hour. An alternative view is that students received feedback on their group work after exam 2 which may have soured their relationships with their classmates, resulting in less optimal collaboration (Nokes-Malach, Zepeda, Richey, & Gadgil, in press).

Another negative relation was finding the between the practice test given before exam 1 and exam 1 performance. Students who used the practice test performed worse on the exam. Perhaps students who reported taking the practice test were more likely to think that they were struggling with the material or needed help. Using the practice test could be viewed as a measure of competence, those who took it might have felt that they either had low prior knowledge or competence. This finding might also be due to the way students are using the practice test. Students were instructed to try to retrieve the information on their own and then check their answers (which were posted a few days after the practice items); however, students could have been superficially using the practice test. Perhaps some students were not trying to retrieve the information on their own and just looking at the answers while others were not checking their answers. Providing strict scaffolds for using a practice test might be one way to alleviate this negative association.

2.7.3 Time management

In students' open-ended responses, time was not a salient aspect of their study descriptions. This finding suggests that students rarely think of time as being one way to study which is consistent with Kornell and Bjork's (2007) interpretations that students do not think spacing one's study time is a strategy that helps memory. It could also be the case that answering questions about timing before the open-ended question resulted in some students not including those factors in their open-ended response because they just reported it. Perhaps due to this low occurrence and awareness of timing being a strategy, there were few relations between the open-ended statements and exam performance. The relations between the open-ended time responses and exam performance were scattered, but the directions of the relations were consistent with prior work. For example, students that reported studying throughout the semester on exam 1 performed better on that exam and students that reported cramming for exam 2 performed worse on that exam. Students that reported studying a week to a few days before the exam performed better on exam 3 than students that did not report studying a week to a few days before the exam.

Considering that I predicted that students would not view time as a strategy, I asked students to respond to a variety of questions aimed at time, including: the number of minutes, the percentage of time they distributed reviewing popular resources, and the number of study sessions. On average, students did not spread out their studying. However, consistent with laboratory work (Kornell, 2009), there was a positive relation between the number of study sessions and exam 2 and exam 3 performance. There was also a negative relation between the percentage of time reviewing the book and exam 3 performance. Interestingly although there was a positive relation between students' open-ended responses and the use of the study guide on exam 3, students who spent less amount of their time reviewing the study guide performed better on the exam. This result suggests that it is more effective for learning if students disperse their time across different materials; perhaps this dispersion invites the use of different study strategies (e.g., comparison). Otherwise, none of the other timing variables were related to exam performance.

2.7.4 Number of strategies

Examining the specific strategies provides details about which specific strategies are related to exam performance. Another approach is to sum across the different study approaches to obtain a count of the total number of study strategies, resources, and time management statements for each exam. Consistently across each exam, the more constructive strategies students reported using, the better they performed on the exam. The number of active strategies was only related to exam 2 performance. This result is consistent with the ICAP hypothesis in that constructive strategies result in better knowledge construction that is more likely to be accurately applied to other situations whereas active strategies result in shallow understanding (Chi, 2009; Chi & Wylie, 2014). The number of resources was positively related to exam 2 and exam 3 performance, but it was not related to exam 1 performance. Students stated that they used slightly fewer resources for exam 2 and 3 than they did for exam 1, suggesting that perhaps students were figuring out which resources were more helpful. The number of time management statements was positively related to exam 1 performance. One explanation for this result is that for exam 1 students provided more statements about spacing study time whereas the later exams involved more statements involving cramming (see Figure 5 and Appendix A.2).

2.7.5 Global change in strategy use

To obtain a larger grain size of whether students changed strategies, students responded to a forced-choice question that asked them whether they changed their strategies from the previous exam: yes or no. More than half of students reported that they did not change their strategies between either exam transition, but when collapsing across the exams, the majority of students changed their strategies at one point. Without controlling for prior exam performance, changing strategies was negatively related to exam 2 performance and not related to exam 3 performance. However, when entering prior exam performance and the interaction between prior exam performance and changing strategies into a model, different patterns emerged. For exam 2, there was no longer a relation between changing strategies and exam performance, but prior exam performance positively predicted exam 2. For exam 3, there was an interaction in which students that performed poorly on the prior exam and changed their strategies performed better on the exam than students that performed poorly on the prior exam and did not change their strategies. There were no differences between the students that did and did not change their strategies and performed well on the prior exam. This result suggests that some students were aware that they were changing their strategies and were productively finding ways to boost their learning. This result might have only appeared at exam 3, because exam 2 was more difficult and/or because exam 3 is the last chance students have to increase their grade.

2.7.6 Relation to exam performance

The relation to exam performance should be taken cautiously. Throughout the course, students learned about cognition and could have been applying what they learned to their learning process. For example, for exam 2, they learned about memory and more effective ways to increase memory (e.g., retrieval is more effective than rehearsal; elaborative encoding is better than rehearsal). Students also learned about analogical comparisons for exam 3. Prior work revealed that student who learned about specific cognitive strategies in their courses believed that the cognitive-psychology-supported strategies were more effective than other strategies students often use (e.g., testing was better than restudying and generating was better than not generating) in comparison to students that did not learn about the strategies (McCabe, 2011). Regardless, it is intriguing that the types of strategies that were related to exam performance replicated across the exams tended to be measured with Likert-scale items, but these relations varied with the open-ended response.

2.7.7 Relation of the measures: The type of questions matter

The type of questions that assess student strategies is an important factor to consider. Do similar measures align and do the parameters of those questions have implications for how those responses relate to student learning? This work revealed that when framing the question to a specific exam, two types of questions sometimes align, but that this depends on the construct. Students open-ended reports on self-explanation and comparison – a concrete and explicit strategy – were related to their Likert-scale items. However, the open-ended metacognitive statement that reflected students' monitoring was only related to metacognitive monitoring Likert-scale measures for the first and third exam. This relation disappeared at exam 2. Metacognitive measures have some history of being difficult to adequately capture with Likert-scale measures (Winne & Perry, 2000; Zepeda, 2016), which might be why there is sometimes a relation and sometimes not.

The use of the open-ended question (although tedious with the amount of time it takes to code) provides insight into the strategies that are at the forefront of students studying habits and reveal which strategies are overt and valued by students. A student may think that a strategy is important to use and therefore rate that they use that strategy regularly, but that might not always be the case. For example, in this work, students reported quizzing or testing themselves slightly more than the only other prior study that used an open-ended question (an average of 19% across the exams versus 10%; Karpicke et al., 2009). This percentage is much lower in comparison to studies that specifically asked students if they use generally used practice problems or tested themselves. Both Hartwig and Dunlosky (2012) and Morehead, Rhodes, and DeLosier (2016) reported that 71% and 72%, respectively, of students marked that they regularly quizzed themselves or practiced problems to study. There were also other differences between prior work and the work presented here: rewriting notes (averaged across exams 16% compared to 33%, 29.9%, 33%, Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Morehead at al., 2016, respectively) highlighting (averaged across exams 13% compared to 22%, 6.2%, 53%, Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Morehead at al., 2016, respectively), and studying with friends (averaged across exams 16% compared to 50%, 26.5%, 48%, Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Morehead at al., 2016, respectively). There were similar responses for creating examples (averaged across exams 4% compared to 4.5% Karpicke et al., 2009) and mixed responses for creating a resource (averaged across exams 25% compared to 15%, 12.29%, 24%, Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Morehead at al., 2016, respectively). Therefore, when the questions are framed to general use (as seen in the prior work cited above), it may not be a reliable source for how students study for specific courses. There is some evidence for this difference as the percentage of students reporting they used a strategy differed between the prior work that used general questions and this work that framed the questions to a specific exam and course. That is, the framing and the prompting within a question matters.

2.7.8 Limitations and future directions

As with any one study, the interpretations of these findings should be taken with caution. Although certain strategies were related to exam performance, it does not mean that those strategies were used effectively or that they caused better performance. Instead, it suggests that students who are aware of these strategies (open-ended) and report using more of these strategies (Likert-scale items) are also students that perform well. This work could be used as a baseline for similar courses in which future work could explore whether supporting these specific strategies in a large-lecture course benefit student learning and performance.

The current work also focused on how students reported behaving outside of the class (their study strategies), but what is not clear is how the in-class demands interacted or affected how students behaved outside of the class. Although this work evaluated two versions of the class, I did not examine whether the in-class demands (warm-up quizzes versus end-of-lecture quizzes, the different types of homework) affected the types of strategies students reported. The types of activities and resources a course provides may result in differential learning outcomes. For instance, a classroom that provides resources that students can use to test themselves easily might result in more students reporting that they quizzed themselves.

Asking students to report on how they studied is a metacognitive process. Students who respond to questions about their studying, have to assess their awareness of their strategies and reflect on their studying techniques. It is possible that asking students about their studying resulted in them engaging in more self-regulatory processes. For example, the questions might have prompted students to be more evaluative about the ways in which they studied, resulting in changes in their study strategies and subsequent learning. Future work could test whether responding to questions about studying throughout a course affects subsequent learning.

The type of knowledge that is covered in specific courses might also have implications for the types of strategies students report using (Wolters & Pintrich, 1998). For example, the courses in this study involve factual, conceptual, and applied knowledge in which the students had to know the topics covered, their conceptual underpinnings, and use inductive reasoning to determine which concepts applied to different situations. The course did not require students to learn how to mathematically problem-solve. Therefore, in a course requiring mathematical procedures or emphasizing more procedural knowledge may have different types of responses to the strategies students report using. Further, those strategies may have different relations to exam performance, depending on which types of knowledge the items evaluate. A productive line of research could examine the types of knowledge these self-reported strategies are related to across different domains. For example, courses that emphasize the link between procedural and conceptual knowledge might have different relations between the study strategies in comparison to courses that only emphasize the procedural or only the conceptual aspects.

For similar courses, this work can serve as a baseline with which instructors could identify areas to intervene with their students. Providing additional scaffolds that support self-explanation, comparison, metacognitive monitoring, and regulation, and spreading out studying might be potential areas to focus on as they were positively related to exam performance. Suggestions on possible scaffolds are discussed in Chapter 5. When considering which types of instructional scaffolds to implement, it is important to understand how these strategies connect and interact with student motivation. Understanding the relation between a subset of these strategies and motivation is examined in the next chapter.

3.0 ADDING MOTIVATION INTO THE MIX: SELF-REGULATED LEARNING ACROSS A SEMESTER

Much work in cognitive science has focused on the cognitive mechanisms of learning, but less work has examined how motivation influences cognitive processing and subsequent learning. Prior work that has examined the relation between student study strategies and their motivations exists primarily in educational psychology, in which researchers examine students' general motivations and broad strategy use, often free of contextual constraints of a specific domain or course (Winne & Nesbit, 2010). Unpacking how student motivation and the use of study strategies work together to result in better learning throughout a semester provides an opportunity to test the self-regulated learning theory (SRL) in an in-vivo setting. Self-regulated learning theories posit that students are self-regulated when they are motivationally and metacognitively in control of their learning process (Pintrich, 2000, 2004; Winne & Hadwin, 1998; Zimmerman, 2000a). This learning process is cyclical in which the phases of learning (forethought/before, performance/during, and evaluation/after) interact with each other and affect subsequent iterations of learning. That is, the motivational and metacognitive factors during one learning experience influence each other and impact subsequent motivation and metacognition.

Extending this perspective to the classroom context, SRL theories posit that when students enter a new course, their dispositional motivational beliefs can impact the motivations they adopt and the strategies they use within the context of the course. These contextually dependent motivational and metacognitive factors continually update and impact each other throughout the course. However, these iterative cycles of SRL are rarely examined in classroom contexts. Prior classroom work tends to examine the relations with SRL models via a one-time measure (e.g., Vrugt & Oort, 2008) or through a pre-posttest design (e.g., Zepeda et al., 2015) (Winne & Nesbit, 2010; Winne & Perry, 2000). Although these macro or more generalized approaches to examining SRL provide insight into how these SRL factors generally work and relate to one another, they do not evaluate the iterative process of SRL.

Do dispositional motivations impact students' contextual motivations and study strategies and does this relation replicate throughout a course? Further, do these contextual factors update or influence each other upon the next iteration of SRL? These questions raise important issues for theory and practice. The first question evaluates the assumptions within SRL theory as learning unfolds over time within an educational context such that one iteration of SRL impacts the next and that the contextual factors mediate the impact of dispositional factors. The second question asks whether the contextually-sensitive factors of SRL (which are malleable and can be scaffolded via instruction) are some of the underlying and contributing mechanisms for learning and subsequent learning experiences.

To answer these questions and to test SRL theory in an educational setting, I examined whether grit and course-framed self-efficacy related to each other, to exam-framed metacognitive study strategies (as described in Chapter 2), and to course performance in a college course. Figure 9 depicts these relations. I focused on grit and self-efficacy as motivational constructs due to their theoretical overlap. Although they are both hypothesized to be related to similar aspects such as effort and persistence, they are distinct in that grit is more stable and self-efficacy is more context-dependent (Bandura, 1977; Duckworth, Peterson, Matthews, & Kelly, 2007). Grit is a person's persistence and interest toward a long-term goal (Duckworth et al., 2007). Self-efficacy is a person's confidence in their ability to succeed in performing a specific goal or task (Bandura, 1977). These specific SRL constructs were chosen to also evaluate the assumption within SRL that state-like constructs mediate the relation between trait-like constructs and performance. In other words, the relation between grit and student performance should be mediated by contextually-dependent factors such as students' self-efficacy and metacognitive strategy use. Therefore, I also examined whether the state-like constructs mediated the relation between grit and performance. Importantly, I evaluated the iterative nature of SRL by examining whether these relations replicated across different time points in the semester. In the next few sections, I describe each of the SRL constructs and prior work examining their relations within SRL.

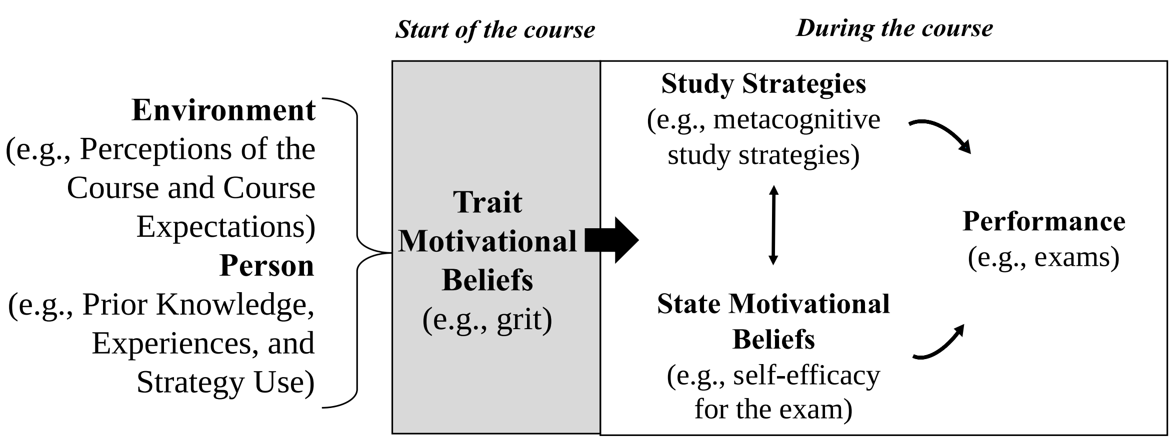


Figure 9. Representation of one cycle of self-regulated learning that unfolds throughout a course

3.1 GRIT

Grit is the effortful persistence and passion for a long-term goal (Duckworth et al., 2007). Grit is conceptualized as a trait-like disposition that influences students' behaviors and choices in a variety of contexts (Duckworth & Quinn, 2009; Reed, Pritschet, & Cutton, 2012). It develops with age and can be encouraged by pursuing interests, deliberate practice, finding purpose, and hope (Duckworth, 2016). In educational settings, people who have more grit engage in more deliberate and effortful practice, have higher attendance, are more likely to not change their major or career, have a greater sense of belonging, engage in more co-curricular activities, and report having more interactions with faculty (Bowman, Hill, Denson, & Bronkema, 2015; Duckworth & Quinn, 2009). They also employ less enjoyable study strategies to overcome difficult situations such as engaging in solitary deliberate practice (Duckworth, Kirby, Tsukayama, Berstein, & Ericsson, 2011). People who earn a college degree have also been shown to have more grit than people who complete some college (Duckworth et al., 2007). Thus, students that are grittier might be more likely to control and monitor their learning to reach their goal of passing a course or doing well in a course.

Some initial work has begun to examine the relation between grit and aspects of self-regulated learning (Arslan, Akin, & Çitemel, 2013; Bowman et al., 2015; Maccann & Roberts, 2010; Weisskirch, 2016; Wolters & Hussain, 2015). However, this work has examined grit as a construct with two distinct aspects, perseverance of effort and holding consistent interests over time (Credé et al., 2016; Duckworth et al., 2007; Duckworth & Quinn, 2009). Perseverance of effort are beliefs about one's effort and theorized to require some amount of metacognitive control in which students purposefully regulate when and where they apply their energy. Consistency of interest involves one's beliefs about one's interest and is theorized to require some amount of motivational control to maintain that interest. Within the grit questionnaire, all the consistency of interest items are reversed and negatively worded (e.g., "I often set a goal but later choose to pursue a different one") whereas perseverance of effort is not (e.g., "Setbacks don't discourage me"). Past work has found that when examining students' self-reports of their general SRL behaviors, effortful persistence has been positively related to a student's self-control, self-efficacy for studying, value, cognitive, metacognitive and motivational strategies whereas consistency of interest has not (Wolters & Hussain, 2015). Both dimensions were positively related to time and study management strategies and negatively related to procrastination. Consistency of interest was not related to GPA, but perseverance of effort was related to GPA (Wolters & Hussain, 2015). These relations have also been found when examining students' self-reported grades and controlling for various self-reported learning strategies (Weisskirch, 2016). Although there has been some discrepancy between the two components of grit, I collapsed both components into one factor as has been done in much prior work.

3.2 GRIT AND ACADEMIC PERFORMANCE

Prior work has revealed mixed findings on the relation between grit and performance. Some work has shown that grit predicts student GPA (Bowman et al., 2015; Duckworth et al., 2007) whereas other work has revealed that grit has not always been related to course grades (Maccann & Roberts, 2010; Strayhorn, 2014; Weisskirch, 2016; Wolters & Hussain, 2015). These conflicting results might be a product of the course difficulty and clarity (e.g., clarity of what will be assessed; Credé et al., 2016). Credé and colleagues posit that high levels of grit might only be related to performance when the outcome is difficult, yet clearly defined. That is, students have to deliberately work toward the performance in which the performance criteria are clearly explained. Thus, the final grades from these different courses might have used different types of requirements that ranged in difficulty which might or might not have been expected by students.

Another aspect of academic performance is attending lecture and participating in lecture activities. Attending lecture is one way to learn the material for the course. It also requires time-management strategies in which students have to allocate time and a plan to attend the lectures. Although attending some of the lectures is optional, it also requires the students to regulate their efforts to attend. Like the time-management strategies and the prior work that has examined the relation between grit and attendance (Bowman et al., 2015; Wolters & Hussain, 2015), I predicted that students with higher grit would also have better attendance than those with lower grit.

3.3 GRIT AND STUDY STRATEGIES

If students are grittier, they persevere and put forth an effort to overcome challenges. Two challenges for students are regulating their learning strategies and learning the material covered in their courses. The types of strategies students employ have implications for how they process the information. Some strategies are constructive in that they require the generation of information and provide the opportunity to engage in sense-making processes (e.g., self-explanations). Other strategies are less constructive but still involve active engagement with the material such that students are manipulating information (e.g., rewriting). As mentioned in Chapter 2, these differential levels of processing have implications for the what is learned and transferred (Barnett & Ceci, 2002; Nokes-Malach & Mestre, 2013; Nokes, 2009). If constructive strategies take more effortful engagement with the material than active strategies, then students that are grittier and are putting forth more effort might engage in more constructive strategies than active strategies.

Prior work has shown that grittier students engaged in more deliberate practice when preparing for the National Spelling Bee, and that those who engaged in more deliberate practice performed better (Duckworth et al., 2011). Deliberate practice involves a focused, planned activity to improve performance, and requires purposeful regulation. The goal of deliberate practice is to improve performance (Ericsson, Krampe, & Tesch-Römer, 1993); therefore, students might be engaging in more effective strategies, such as constructive strategies, to improve their subsequent performance.

Some past work has supported this hypothesis as grit has been related to different types of strategies such as study strategies and time management (Arslan et al., 2013; Bowman et al., 2015; Wolters & Hussain, 2015). These study strategies include rehearsal, elaboration, organization, planning, monitoring and management of learning strategies (Arslan et al., 2013; Wolters & Hussain, 2015). Although these strategies included some constructive strategies (e.g., managing one's learning), research since the development of the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991) has revealed that some of these strategies (e.g., rehearsal, elaboration, organization) are not as effective as other strategies, such as self-explanation, comparison, and retrieval practice (Karpicke & Blunt, 2011; O'Reilly, Symons, & MacLatchy-Gaudet, 1998). Therefore, in this work, I explored whether grit was related to the types and number of active and constructive strategies students reported using in an open-ended question. I also evaluated whether grit was positively related to the self-reported use of constructive strategies measured via a Likert-scale questionnaire.

More globally, students also have the opportunity to change their strategies between each exam transition. Given persistence is inherit within grit, students that are grittier might also be less likely to generally change their strategies. However, if students did not perform well on the prior exam, then they might be more likely to change their strategies to persist in earning a better grade. Therefore, I examined whether there was an interaction between students' prior exam performance and their grit in relation to whether they reported that they changed their study strategies.

Investigating these different aspects of strategy use provides a broad analysis of which types of strategies were related to grit and SRL. To sample these different aspects of studying (active and constructive strategies, changing strategies), I used different types of measures. I used open-ended questions to assess students' study techniques, Likert-scale items to assess specific constructive strategies, and forced-choice questions to assess global change. The goal for using these different types of measures was to addresses the lack of measurement in prior SRL work, and to evaluate whether SRL relations replicated at different time points during a course.

3.4 GRIT AND SELF-EFFICACY

A prominent construct within self-regulated learning is self-efficacy. Self-efficacy is one's confidence in one's abilities to succeed at a specific task (Bandura, 1977; Pajares, 1996, 2008; Schunk & Pajares, 2009; Zimmerman, 2000b). It is predicted to guide the behaviors students enact and contribute to their perseverance in the face of difficulties. Self-efficacy is contextually sensitive and malleable (Bong & Skaalvik, 2003) and develops based on past mastery experiences, social comparison (vicarious experiences), verbal persuasion, and physiological reactions (Bandura, 1986, 1997). Those who are more self-efficacious are effortful, have a sense of agency, choose challenging goals, and persevere (Zimmerman, 2000b). In educational contexts, they tend to stay in their majors longer and earn higher grades (Lent, Brown, & Larkin, 1984). Meta-analytic reviews have shown that self-efficacy has a positive relation to time on task and academic performance as measured by standardized tests, GPA, and class performance (Multon, Brown, & Lent, 1991; Richardson, Abraham, & Bond, 2012). Self-efficacy has also been shown to predict academic achievement above and beyond other motivational concepts such as task value and affective components, including test anxiety (Robbins et al., 2004). This contribution suggests that self-efficacy is providing students encouragement to engage in learning the materials, boosting their confidence and limiting their doubts. Grit has also been shown to have a positive relation to performance when controlling for prior performance (Bandura, 1997). Similar to grit, prior work has found positive associations between self-efficacy and self-reported strategies from the MSLQ (Duncan & McKeachie, 2005; Wolters & Hussain, 2015). Again, the strategies measured by the MSLQ are considered less constructive than some of the strategies I explored in this work (e.g., comparison) and some recent work calls into question the validity of the strategies captured by the factors in MSLQ (Dunn, Lo, Mulvenon, & Sutcliffe, 2012).

Given the empirical overlap of self-efficacy and grit and their theoretical overlap in relating to more effort and persistence, I explored how these two constructs related to each other throughout a course. If SRL theorists posit that contextually-dependent factors mediate the relation between dispositional measures on learning, then examining grit and self-efficacy repeatedly over time within this frame would be a rigorous test of this assumption. Few studies have examined the general relation between examining how they generally relate to each other in an academic context (Wolters & Hussain, 2015). Wolters and Hussain (2015) found that grit and self-efficacy of studying are positively related to one another. They also found that both grit and self-efficacy were positive predictors of cognitive strategies (rehearsal, elaboration, organization) and metacognitive strategies (planning, monitoring, and managing learning strategies). Self-efficacy was not related to timing and environmental strategies when grit was added into the mix. These findings reveal that grit and self-efficacy contribute to some similar and different types of strategies. However, this work should be interpreted with caution as they examined students' general self-efficacy for studying (not a contextually specific situation) and their general strategy use (how they use these strategies generally, again not contextually specific). In this work, I examined whether grit and self-efficacy were related to one another and how they functioned within a course over time. If grittier students engage in persistence and deliberate practice (with the purpose of improving performance), then that practice should not only result in more effective strategies but also boost students' confidence in their abilities to perform well (i.e., self-efficacy) as they are acquiring more knowledge and improving their performance. Self-efficacy might also explain the connection between grit and exam performance (in addition to the constructive strategies) as students that are more self-efficacious might be employing more motivational strategies during both studying and test-taking (e.g., self-talk such as "you can do this" and "you prepared for this"), resulting in more persistence with difficult information, deeper engagement, and better performance.

3.5 CURRENT STUDY

Central to self-regulated learning models is the assumption that contextually-dependent factors (self-efficacy, study strategies) act as mediators between students' dispositional characteristics (grit) and their performance (Pintrich, 2004). The current study evaluated this assumption by first examining whether grit was positively related to strategy use, course performance, and self-efficacy throughout a semester. Then, I applied mediation analyses to evaluate (1) whether the contextual factors mediated the relation of grit on exam performance, and (2) whether prior strategy use, self-efficacy, and exam performance mediated the relation between grit the subsequent strategy use and self-efficacy that occurred in the next cycle of SRL (Figure 10). This second set of mediation analyses provides a more informative understanding of how these constructs related and impacted each over time – it revealed whether the iterative nature of SRL happens throughout a course.

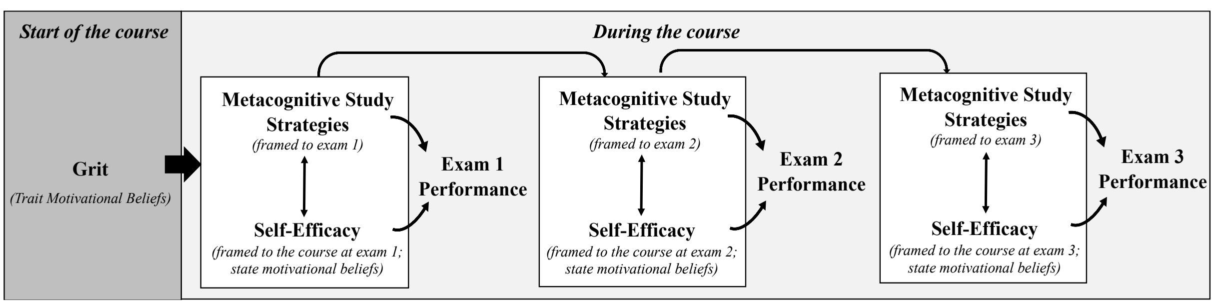


Figure 10. Theoretical model of self-regulated learning over the course of a semester.

I hypothesized that:

1. Grit would be positively related to the number of constructive strategies, the self-reported use of constructive strategies, attendance, exam performance, and self-efficacy throughout a semester. Grit might be positively related to the number of active strategies.

    a. Given persistence is inherit within grit, students that are grittier might also be less likely to change their strategies. However, if students did not perform well on the prior exam, then they might be more likely to change their strategies to persist in earning a better grade.

2. The relation between grit and exam performance would be mediated by concurrent self-efficacy and study strategies, thus demonstrating the assumption within SRL that the contextually-dependent factors mediate the relation of dispositional variables.
3. Prior SRL cycles would affect the subsequent study strategies and self-efficacy such that:
    a. Exam performance would partially mediate the relationship between the relation of grit and subsequent strategy use and self-efficacy.
    b. Prior study strategies and self-efficacy would partially mediate the relation between grit and subsequent self-efficacy and strategy use.
4. All relations predicted above would replicate across the semester.

3.6 METHOD

To investigate the hypotheses presented above, I used the same dataset as described in Chapter 2. However, there were additional variables included in these analyses which I describe in detail below.

3.6.1 Participants

For information about participants, see section 2.5.1.

3.6.2 Materials

3.6.3 Questionnaires

Students completed four questionnaires throughout the course that assessed their motivation and metacognitive study strategies throughout the semester. Each questionnaire began with the following general directions, “We are interested in your thoughts and feelings about cognitive psychology. Please answer these questions as honestly as you can. There are no right or wrong answers -- we only want to know what you think about cognitive psychology”. These questions assessed student motivation and their study strategies, which I describe below. These questionnaires were validated (see Appendix B for details).

3.6.3.1 Student motivation

Students responded to several questionnaires throughout the course. The initial questionnaire assessed students’ beliefs about their grit and self-efficacy of the course (Table 9). The instructions asked that students respond to the questions within the context of the Cognitive Psychology course. For grit, students responded to three items using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). These items were adapted from the Short Grit Scale (Duckworth & Quinn, 2009). These exact items were also included in a final questionnaire to measure the stability of grit over a course.

Students' initial and final self-efficacy for the course was measured with 5 items with a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). For the first and second exam, we adapted these items were condensed into three items. These items used the same 6-point Likert scale. We also assessed other motivational variables (e.g., mastery-approach, theories of intelligence, theories of intelligence for cognitive psychology, fascination, values), but those items are beyond the scope of this work.

Table 9. *Motivation items.*

Timing	Type	Item
Initial & Exam 3	Grit	I often set a goal but later choose to pursue a different one. (Rev) I have difficulty maintaining my focus on projects that take more than a few months to complete. (Rev) I finish whatever I begin.
	Self-Efficacy	I am confident I will do well on cognitive psychology tests. I am confident I will do well on cognitive psychology projects and assignments. I am confident I will be able to help my classmates with cognitive psychology assignments and projects. If I read a newspaper article on cognitive psychology, I could understand it. If I wanted to, I could be good at conducting cognitive psychology research.
Exam 1 & 2	Self-Efficacy	I am confident I will do well on cognitive psychology tests. I am confident I will do well on cognitive psychology projects and assignments. I am confident I will be able to help my classmates with cognitive psychology assignments and projects.

3.6.3.2 Metacognitive study strategies

The study strategies questionnaire assessed whether students used different strategies as they studied for the subsequent exam and are a subset of the items presented in Chapter 2. In Chapter 2, metacognitive study strategies included three aspects of studying: study strategies, resources, and time management. For this chapter, I only examined study strategies. See Table 3 in section 2.5.2.1 for examples of these items and Appendix A for the coding protocol for the open-ended statements. For the Likert-scale items, a composite score for the study strategies was calculated by taking the average of the Likert-scale study strategies (self-explanation, comparison, metacognitive regulation, and metacognitive personal knowledge) for each exam.

3.6.3.3 Attendance

For both courses, attendance was required. Students were allowed to miss two days and could still obtain full credit for attendance. For non-exam class days, teaching assistants handed out attendance worksheets during the first 10 minutes of class and collected one attendance paper from each student at the end of class. There was a total of 25 classes (outside of exam days).

3.6.3.4 Exam scores

The exams are described in section 2.5.2.2.

3.6.4 Procedure

Two weeks into the semester, **s**tudents completed an initial questionnaire to gauge their initial motivations for the course. Then before each exam, they completed a questionnaire assessing their study strategies and self-efficacy. The instructors recorded student attendance for each lecture. On the last day of class (day of exam 3), students responded to the final questionnaire that examined strategies and motivations. See Figure 1 in Chapter 2 for an overview of the design.

3.7 RESULTS

Before examining the specific hypotheses, I first evaluated whether grit was a stable, trait-like motivation and whether self-efficacy was flexible, state-like motivational construct by examining their reliability in change. The second set of analyses examined the relation of grit to study strategies, self-efficacy, exam performance, and attendance. The relation between grit and the different study strategies was evaluated with Kendall Tau's partial correlations using the ppcor package in R (Kim, 2015) to remove the variance explained by student sex, race/ethnicity, age, high school GPA, and the class they were enrolled in and to reflect the dichotomy in the variables and the non-normality. These correlations are presented in a graphical form which was derived from the corrplot package in R (Friendly, 2002; Murdoch & Chow, 1996). The relation between grit and self-efficacy, exam performance, and attendance was evaluated with multilevel models using lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017) packages in R.

The third set of analyses tested the links between these constructs within the self-regulated learning model using different mediation models. For the mediation models, I used PROCESS model 4 and model 80 (Hayes, 2018) with an HC3 estimator to better account for any homoscedastic errors in the estimation (Hayes & Cai, 2007). This method provided an estimation of both the direct and indirect paths with a 95% confidence interval for both the direct and indirect effects. A 10,000 bootstrap method was also applied as suggested by Hayes (2018). Bootstrapping means that the effects were estimated from resampling the data that was repeatedly drawn from the original dataset with replacement. Because PROCESS provides the regression coefficients in unstandardized form, I standardized all the variables prior to entering them into the model. This approach allowed for easier comparison within the models. The results are significant if the bootstrapped CI does not contain 0.

For all analyses, I applied effects coding for the dichotomous variables in order to examine the models at baseline: sex (male = - 0.5, female = 0.5), underrepresented minority status (majority = - 0.5, underrepresented minority = 0.5), age, prior high school GPA, and class type (typical = - 0.5, scaffolded = 0.5), were included as random intercepts for the multilevel models and covariates for the correlations and mediation models. For some of the models, additional random intercepts or covariates were included and for those instances, the additional random intercept or covariate is stated. Outliers were removed if they were +/- 3 SDs from the mean and assumptions were tested. The same pattern of results emerged with or without including outliers. For all results, the alpha level was set at .05 and relations for *p*-values less than .05 were reported (Keppel & Wickens, 2004).

3.7.1 Stability and flexibility of the motivational measures

According to theory, grit is a trait motivational construct whereas self-efficacy is a state motivational construct that is contextually sensitive. To test this assumption, I evaluated whether grit was stable and whether self-efficacy fluctuated across the course using the reliable change index (RCI; Christiansen & Mendoza, 1986; Jacobson & Truax, 1991, Bauer et al., 2004). The RCI determines whether student responses to a measure is due to actual changes in student responses to the construct between observations and not to imperfections in the measurement. This approach has been used with other motivational measures to determine if students reliably changed their responses (Bernacki et al., 2015).

After applying the RCI to grit measured at the start and end of the course, there were 8 students (2%) that changed their grit throughout the course (4 increased and 4 decreased). Grit was stable over the course for 322 students (98%) which is consistent with theory stating it is a trait-like motivation (Duckworth et al., 2007; Duckworth & Quinn, 2009).

Unlike grit, self-efficacy is theorized to be contextually sensitive. Therefore, I predicted that students' self-efficacy would fluctuate across the semester. Using the RCI, I evaluated how many students reliably changed their responses to the self-efficacy scales. At the exam 1 and exam 2 transition, 274 students maintained their self-efficacy for the course, 31 increased and 25 decreased. At the exam 2 to exam 3 transition, 233 students maintained their self-efficacy, 66 increased, and 31 students decreased. Together this set of results is consistent with theory in which the majority of students maintained their endorsements of grit (a more stable, trait-like construct), and more students changed their endorsements of self-efficacy (a more flexible, state-like motivation).

3.7.2 Examining the relation between grit and study strategies

According to the ICAP framework (discussed in Chapter 2), constructive strategies require a more effortful level of engagement than active strategies (which require a minimal amount of effortful engagement). Therefore, grit should be positively related to constructive strategies as more effortful engagement requires more persistence to engage. To evaluate this hypothesis, I used Kendall Tau's partial correlations with the ppcor package in R (Kim, 2015) to remove the variance explained by student sex, race/ethnicity, age, high school GPA, and the class they were enrolled in and to reflect the dichotomy in the variables and the non-normality. These correlations are presented in a graphical form which was derived from the corrplot package in R (Friendly, 2002; Murdoch & Chow, 1996). As in Chapter 2, the results are separated by measurement type – open-ended and Likert-scale.

3.7.2.1 Relation between grit and the open-ended study strategies

The open-ended strategies included: rewriting, highlighting, summarizing, quizzing, creating examples, analogically comparing, self-explaining, and metacognitively monitoring (Figure 11). Within the active study strategies, rewriting was the only strategy that was positively related to grit, and this relation only occurred at exam 2 (r_t = .09, p = .01). Within the constructive study strategies, quizzing and self-explaining were the only types that were related to grit. Quizzing was consistently related to grit for all three exams (r_t = .09, p = .02, r_t = .11, p = .003, r_t = .11, p = .005, respectively). Self-explaining was only related to grit at exam 1 (r_t = .08, p = .03). From these relations, it is evident that more of the constructive strategies were positively related to exam performance than the active strategies, even when taking into account the disproportional number of active (1/9 = 11% of the strategies were related to exam performance) versus constructive strategies (4/15 = 26% of strategies were related to exam performance).

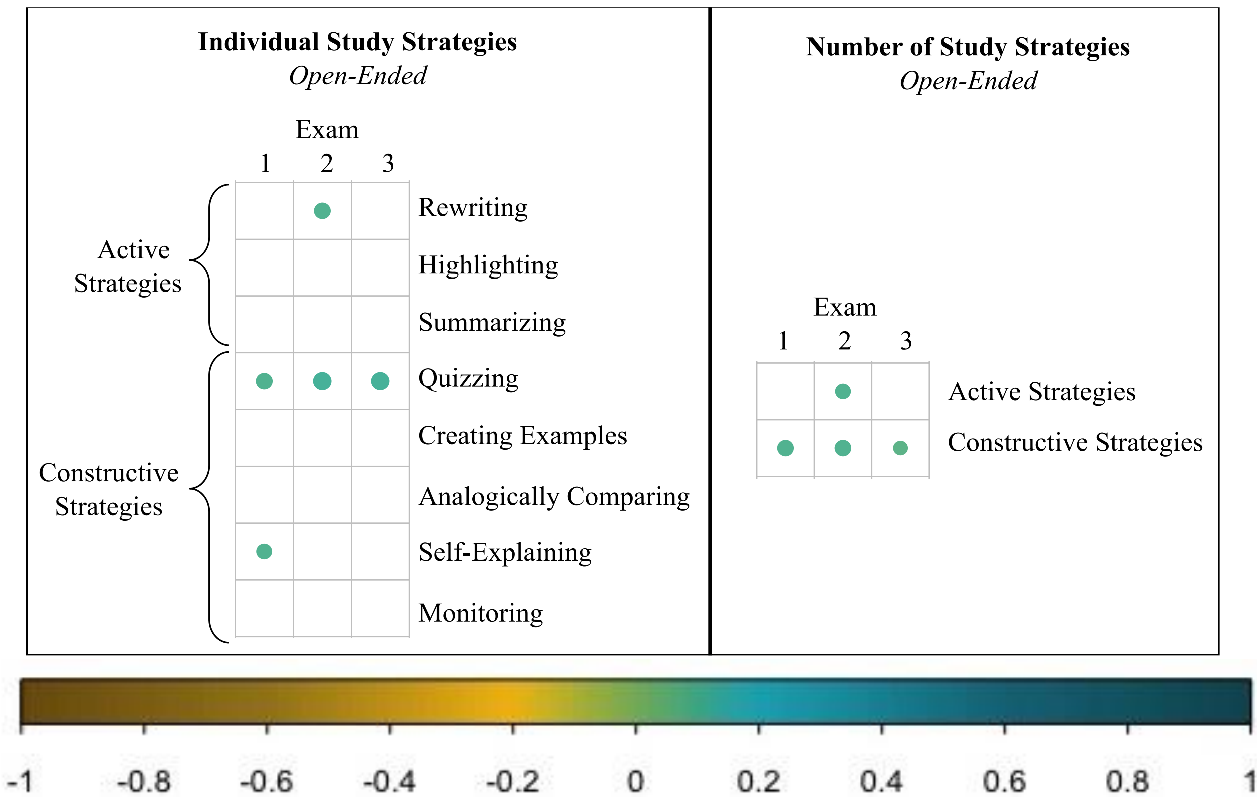


Figure 11. Corrplot of the correlations between grit and the open-ended study strategies for each exam. All circles represent p < .05. The heat map represents the r-value.

Another approach to examining the relation between grit and study strategies is to evaluate the number of strategies students used within each type of strategy (active vs.

constructive). See Table 10 for descriptive statistics for these counts. Grit was positively related to the number of constructive strategies for all three exams (r_t = .09, p = .01, r_t = .09, p = .01, r_t = .07, p = .049, respectively). Unlike the constructive strategies, active strategies were only positively related to grit for exam 2 (r_t = .01, p = .85, r_t = .08, p = .03, r_t = .03, p = .37, respectively).

Table 10. *Counts for the number of study, constructive, and active strategies and resources for each exam*

	Exam 1				Exam 2				Exam 3			
Strategy	*M*	*SD*	Min	Max	*M*	*SD*	Min	Max	*M*	*SD*	Min	Max
Active	0.45	0.65	0	2	0.28	0.51	0	2	0.27	0.55	0	3
Constructive	1.11	0.92	0	4	1.01	0.96	0	4	0.88	0.82	0	3

3.7.2.2 Relation between grit and the Likert-scale constructive strategies

The Likert-scale measures captured students self-reported use of self-explanation, analogical comparison, metacognitive monitoring, and metacognitive regulation. The relations between these constructive strategies and grit were examined individually and with a composite score (Figure 12). Each of constructive strategies was positively related to grit for all of the exams. The composite score was also positively related to grit for each of the exams.

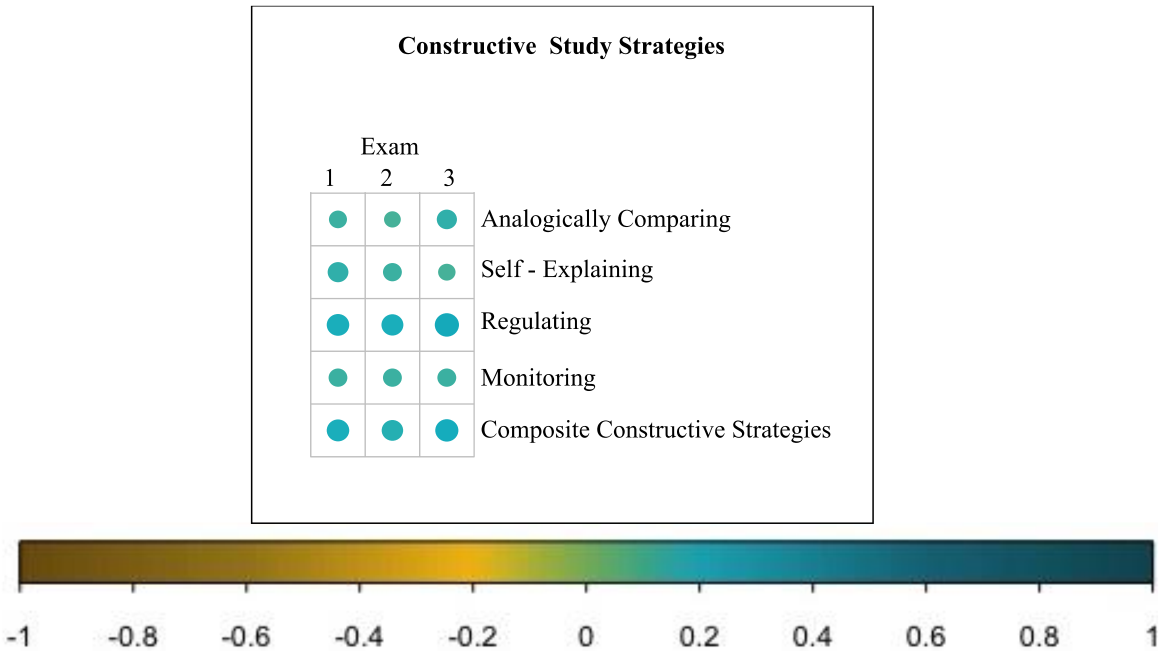


Figure 12. Corrplot of the correlations between exam performance and the open-ended questionnaire. All circles represent $p < .05$. The heat map represents the r-value.

3.7.2.3 Relation between grit and change in strategy use

Grit involves persistence and consistency, but also the belief that one will overcome obstacles. Therefore, there might be an interaction between grit and exam performance on the likelihood students reported changing their strategies. For example, students that performed well on the prior exam and were grittier would not change their study strategies, but those that performed poorly and were grittier would be more likely to change strategies. Students that are less gritty would not change their strategy use. To examine this relation, I used two multilevel logistic models predicting whether students stated that they changed their strategies (change from exam 1 to exam 2, exam 2 to exam 3) with the demographic and course random intercepts. Between the first and second exam, 187 students stated they did not change their strategies and 143 stated they did. Between the second and third exam, 211 students stated they did not change their strategies and 119 stated they did.

Both models revealed that grit was not related to the change in their study strategies (Table 11). There was also no interaction between grit and prior exam performance for either model. However, for both models, prior exam performance was related to change in strategy use such a one unit increase in performance results in the decrease of changing strategies by 0.88 times for exam 1 to exam 2 transition and by 0.93 for exam 2 to exam 3 transition. In other words, the better students performed, the less likely they were to change their strategies.

Table 11. *Output for logistic multilevel models predicting students' responses to changing their strategies with grit*

Exam Transition	Variable	Estimate	SE	*z*-value	Exp(*B*)	95% CI	*p*-value
	(Intercept)	-0.27	0.13	-2.15	0.76	[0.60, 0.98]	.03
Exam 1 to 2	Grit	-0.10	0.18	-0.55	0.91	[0.64, 1.29]	.58
(*N* = 326)	Exam 1 Performance	-0.13	0.02	-7.05	0.88	[0.85, 0.91]	<.001
	Grit: Exam 1 Performance	-0.03	0.03	-1.16	0.97	[0.92, 1.02]	.25
	(Intercept)	-0.73	0.24	-3.03	0.48	[0.30, 0.77]	.002
Exam 2 to 3	Grit	-0.16	0.18	-0.89	0.85	[0.60, 1.22]	.38
(*N* = 326)	Exam 2 Performance	-0.07	0.01	-5.35	0.93	[0.91, 0.96]	<.001
	Grit: Exam 2 Performance	-0.02	0.02	-1.17	0.98	[0.94, 1.02]	.24

3.7.3 Examining the relation between grit and self-efficacy for cognitive psychology

Given the theoretical similarities between grit and self-efficacy and their relations to similar engagement (e.g., persistence and effort), I predicted grit would be positively related to self-efficacy for cognitive psychology at each of the three exams. Consistent with this hypothesis, grit was positively related to self-efficacy for cognitive psychology (Table 12)[4]. For each unit increase in grit, self-efficacy increased by 0.26 units for exam 1, 0.26 units for exam 2, and 0.30 units for exam 3, holding all else constant.

[4] Grit also predicted self-efficacy when controlling for prior self-efficacy.

Table 12. *Multilevel models predicting self-efficacy with grit*

Model	Variable	Estimate	SE	β	*SE*(β)	*df*	*t*-value	*p*-value	R^2
Exam 1	(Intercept)	0.00	0.03	0	0	50.05	0.03	.97	.14
Self-Efficacy	Grit	0.26	0.04	0.31	0.05	315.60	5.78	<.001	
(N= 321)									
Exam 2	(Intercept)	0.01	0.15	0	0	1.39	0.09	.94	.10
Self-Efficacy	Grit	0.26	0.05	0.27	0.05	315.01	5.10	<.001	
(N= 324)									
Exam 3	(Intercept)	0.03	0.10	0	0	1.00	0.34	.79	.15
Self-Efficacy	Grit	0.30	0.05	0.31	0.05	322.50	5.89	<.001	
(N= 326)									

3.7.4 Examining the relation between grit and attendance behaviors

Within the courses, attendance was required to earn participation points. However, students were allowed to miss two days without losing any participation points. On average students attended 93.96% (SD = 8.64) of non-exam class days. Therefore, I compared the grit scores of students that attended every lecture versus those that missed more than their two free days, which reflects poorer time management skills (i.e., attended less than 23 lectures). Fifty-seven students missed more than two lectures, and 130 attended every lecture[5]. Students that attended every class were coded as a 1 and students that missed more than two days were coded as a 0. A multilevel model with the with the demographic and course random intercepts revealed that students who attended every class had higher grit scores (*M* = 3.53, *SD* = 0.68) than students that missed more than two days (*M* = 3.30, *SD* = 0.67, Table 13).

Table 13. *Multilevel models predicting grit by student attendance type*

Variable	*B*	*SE*	*df*	β	*SE*(β)	*t*-value	*p*-value	R^2
(Intercept)	3.23	0.16	1.30	0	0	19.69	.01	.05
Missed more than 2 classes	Ref.							
Attended every class	0.22	0.11	180.32	0.15	0.07	2.04	.04	

[5] Data from 141 students were excluded from this analysis as they did not attend every lecture but missed two of their "free" days. The other two groups represent the extremes.

3.7.5 Examining the relation between grit and exam performance

Performance was measured throughout the course with three non-cumulative exams. Aligning with prior work, I predicted that grit would be positively related to exam performance. One multilevel model with grit predicting exam performance was applied to each exam with the demographic and course random intercepts. The models revealed that grit was positively related to performance exam 1 and exam 2 (Table 14). Contrary to my prediction, grit was not related to exam 3 performance although there was a trend for them being positively associated.

Table 14. *Multilevel models predicting exam performance with grit*

Model	Variable	*B*	*SE*	β	*SE*(β)	*df*	*t*-value	*p*-value	R^2
Exam 1	(Intercept)	-0.74	0.66	0	0	0.13	-1.12	.79	0.49
(*N* = 326)	Grit	1.52	0.65	0.12	0.05	292.59	2.33	.02	
Exam 2	(Intercept)	-1.07	0.74	0	0	1.61	-1.43	.32	0.43
(*N* = 326)	Grit	1.67	0.78	0.11	0.05	312.17	2.16	.03	
Exam 3	(Intercept)	-0.30	1.40	0	0	0.87	-0.21	.87	0.27
(*N* = 326)	Grit	1.22	0.70	0.09	0.05	306.98	1.74	.08	

3.7.6 Testing assumptions of SRL theories

The next set of analyses evaluated whether the contextual factors mediated the relation between grit and exam performance, whether one SRL cycle impacted the subsequent cycle, and whether these relations replicated. For these analyses, PROCESS models were applied and are described below. Due to the count and ordinal aspects of the open-ended study strategies and attendance, these strategies and performance behaviors were not analyzed in this section. Instead, I used the composite score of the Likert-scale constructive study strategies, exam performance, and self-efficacy for cognitive psychology for all the models. Outliers were identified and removed from all mediation analyses (*N* = 6) resulting in 324 students. The same pattern of results existed with or without the outliers. The demographic and course variables as indicated at the beginning of the results section were included as covariates for all mediation analyses. The Kendall's Tau partial correlations for these variables are presented in Figure 13.

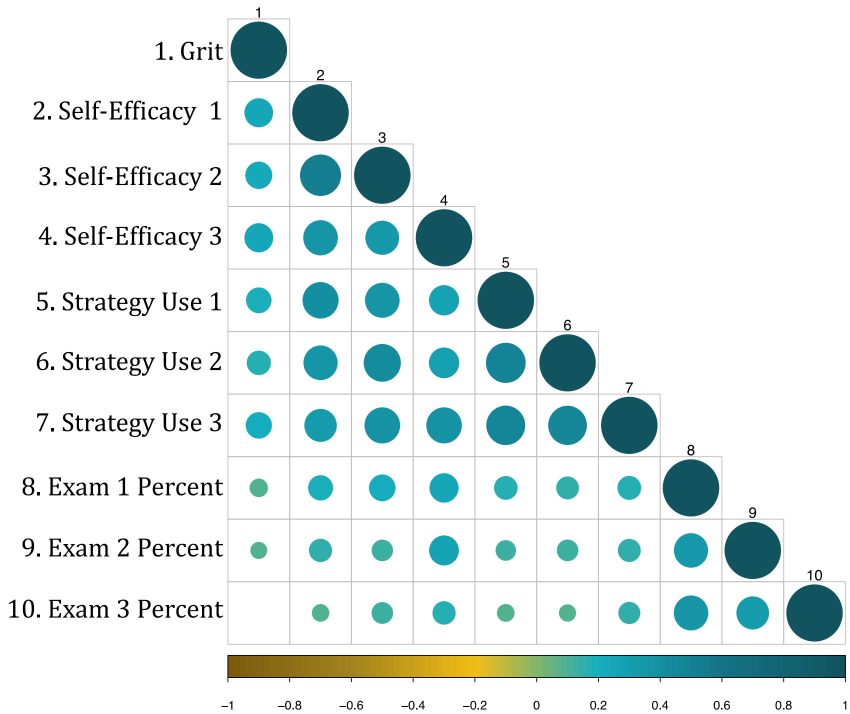


Figure 13. Corrplot of the kendall's tau partial correlations between all the variables included in the mediation analyses, controlling for gender, representation, high school grade point average, age and class. All circles represent $p < .05$. The heat map represents the r-value.

3.7.6.1 Do contextually-dependent factors mediate the relation between grit and exam performance?

An assumption in SRL is that more contextually-dependent factors mediate the relation of dispositional measures. To test this assumption, I investigated whether self-efficacy and the study strategies students reported using for each exam mediated the relationship between grit and exam performance (Figure 14). That is, do self-efficacy and study strategies serve as a mechanism through which grit positively relates to exam performance? To test this question, I used PROCESS model 4 with self-efficacy and constructive strategy use as parallel mediators for each exam. The demographic and course variables were also entered as covariates into each of the models. PROCESS model 4 produces three regressions (see Appendix C.1). For example, for the model presented in Figure 14 for exam 1, the first regression regresses grit on exam 1 self-efficacy with the inclusion of the covariates. The second regresses grit on exam 1 constructive strategy use with the inclusion of the covariates. The third regression regresses all of the variables on exam 1 performance. For each model, I reported the direct and indirect effects of grit on the respective exam performance. All continuous variables were standardized such that the coefficients represent the z-scores or the number of standard deviations above (positive) or below (negative) the means. Although the PROCESS macro provides unstandardized coefficients, standardizing the variables prior to running the models resulted in a standardized coefficient (i.e., the number of standard deviations below or above the mean). See Appendix C.1 for all model coefficients and details.

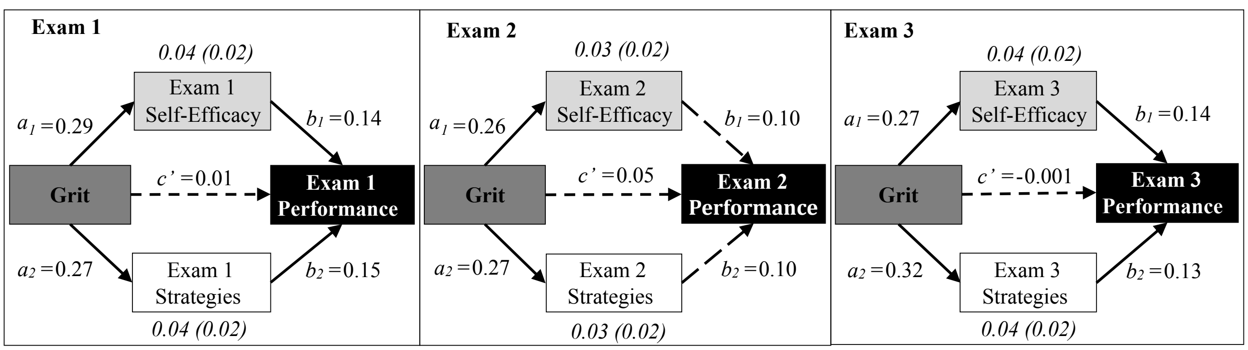


Figure 14. Mediation model for grit, self-efficacy, constructive strategies, and exam performance, controlling for demographic and course variables. The indirect effects are represented in italics with the SE in parentheses next to the respective variable through which the indirect path flows. Black dashed lines indicate a non-significant relation.

Mediation analyses revealed that there was not a direct effect of grit on exam 1 performance, after accounting for the baseline of self-efficacy and constructive strategy use and the covariates at exam 1, $B = 0.01$, $p = 0.87$; CI(*SE*), [-0.11, 0.13] (0.06). There was an overall indirect effect, $B = 0.08$, CI(*SE*): [0.04, 0.13] (0.02). Specifically, there were indirect effects of grit on exam 1 performance through self-efficacy, $B = 0.04$, CI(*SE*): [0.01, 0.08] (0.02) and exam 1 constructive strategy use, $B = 0.04$, CI(*SE*): [0.01, 0.09] (0.02). In other words, for exam 1, self-efficacy and the use of constructive study strategies served as underlying mechanisms of grit on exam performance. The contextually-dependent measures explained the relation of grit on exam 1 performance.

A similar pattern emerged for exam 2. There was not a direct effect of grit on exam 2 performance, after accounting for the baseline of self-efficacy and constructive strategy use and the covariates at exam 2, $B = 0.05$, $p = 0.37$, CI(*SE*): [-0.06, 0.16] (0.06). There was an overall indirect effect, $B = 0.05$, CI(*SE*): [0.02, 0.10] (0.02). However, when examining the specific indirect paths, the paths were not significant. There were trends in which there were indirect paths of grit on exam 2 performance through self-efficacy, $B = 0.03$, CI(*SE*): [-0.01, 0.07] (0.02), and exam 2 constructive strategy use ($B = 0.03$, CI(*SE*): [-0.01, 0.07] (0.02). In other words, when accounting for baseline self-efficacy and constructive strategy use at exam 2, a similar pattern that was seen at exam 1 emerged between grit and exam 2 performance.

For exam 3, the same pattern replicated. There was no direct effect of grit on exam 3 performance, after accounting for baseline self-efficacy and constructive strategy use and the covariates at exam 3, $B = -0.001$; $p = .98$, CI(SE): [-0.12, 0.12] (0.06). There was an overall indirect effect, $B = 0.08$, CI(*SE*): [0.04, 0.13] (0.02). Specifically, there were indirect effects of grit on exam 3 performance through self-efficacy, $B = 0.04$, CI(*SE*): [0.04, 0.09] (0.02) and exam 3 constructive strategy use, $B = 0.04$, CI(*SE*): [0.002, 0.08] (0.02). In other words, for exam 3, self-efficacy and the use of constructive study strategies served as underlying mechanisms of grit on exam performance. The contextually-dependent factors explained the relation of grit on exam 3 performance.

3.7.7 Examining the impact of one SRL cycle on subsequent constructive strategy use and self-efficacy for cognitive psychology

3.7.7.1 Does the previous SRL cycle effect students' self-efficacy for cognitive psychology in the next SRL cycle? And does the previous SRL cycle explain the relation between grit and subsequent self-efficacy?

SRL theories have the assumption that one cyclical iteration of learning can impact the subsequent iterations. For example, if students employed constructive study strategies and performed well on the exam, then they might increase their self-efficacy by the next exam. To test this assumption, I expanded upon the models presented in Figure 14 to evaluate whether the initial cycle impacted students' subsequent self-efficacy. Given the timing of the measures, grit could have an indirect effect on subsequent self-efficacy through prior self-efficacy, prior strategy use, through those measures through exam performance, or through exam performance. Therefore, I used PROCESS model 80, as depicted in Figures 15 and 16. This model produces four separate regressions. For example, for the model presented in Figure 15, the first regression regresses grit on exam 1 self-efficacy with the inclusion of the covariates. The second regresses grit on exam 1 constructive strategy use with the inclusion of the covariates. The third regresses grit, exam 1 self-efficacy, and exam 1 constructive strategy use on exam 1 performance with the inclusion of the covariates. The fourth regression regresses all of the variables on exam 2 self-efficacy. For each of the models, the regressions and model details are presented in Appendix C.2.

The first model examined the effect of the exam 1 SRL cycle on self-efficacy at exam 2. Mediation analyses revealed that there was not a direct effect of grit on exam 2 self-efficacy, after accounting for the baseline of exam 1 self-efficacy, exam 1 constructive strategy use, exam

1 performance, and the other demographic and course covariates, B =0.06; p = 0.14, CI(SE): [-0.02, 0.14] (0.04). There were several indirect effects of grit on exam 2 self-efficacy (Figure 15; Table 15). There were indirect effects of grit through (1) exam 1 self-efficacy, (2) exam 1 constructive strategy use, (3) exam 1 self-efficacy through exam 1 performance, and (4) exam 1 constructive strategy use through exam 1 performance. There was one indirect effect that was not significant (as indicated by the CIs containing 0) in which the effect of grit on exam 2 self-efficacy did not indirectly go through exam 1 performance. These results revealed that the first SRL cycle had an effect on the self-efficacy for the second SRL cycle, supporting SRL theory. Moreover, the relation of grit on exam 2 self-efficacy was explained by the contextually-dependent factors at the first exam. The next model evaluated whether the second SRL cycle had a similar effect on the third and final SRL cycle.

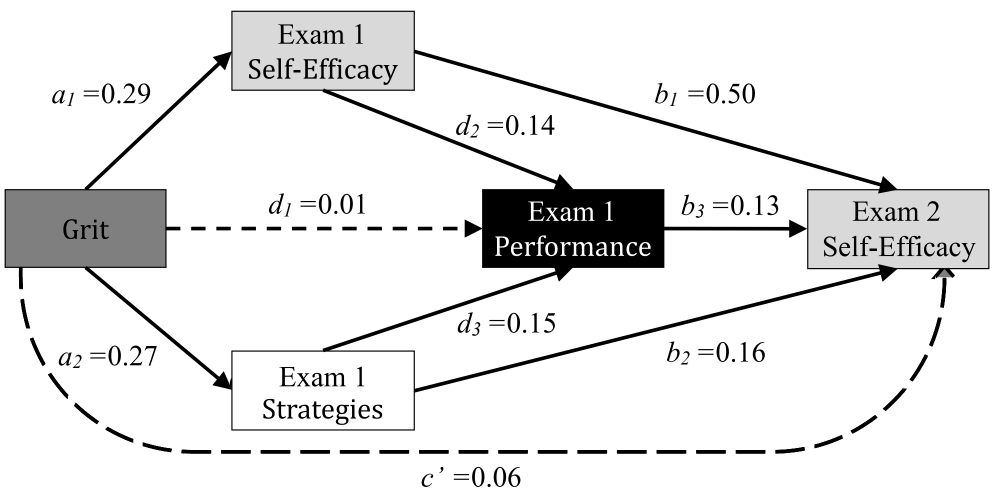


Figure 15. Mediation model for grit, exam 1 self-efficacy, exam 1 constructive strategies, exam 1 performance, and self-efficacy for exam 2, controlling for demographic and course variables. Black dashed lines indicate a non-significant relation.

Table 15. *Coefficients and inferential statistics for the indirect effects for the model depicted in Figure 15*

Indirect Effect Path	Coefficients and Inferential Statistics
Overall Indirect Effect	*B* = 0.20; CI(*SE*): [0.12, 0.29] (0.04)
Grit → Self-efficacy at E1 → Self-efficacy at E2	*B* = 0.15; CI(*SE*): [0.08, 0.22] (0.03)
Grit → Strategy use at E1 → Self-efficacy at E2	*B* = 0.04; CI(*SE*): [0.01, 0.09] (0.02)
Grit → E1 performance → Self-efficacy at E2	*B* = 0.001; CI(*SE*): [-0.02, 0.02] (0.01)
Grit → Self-efficacy at E1 → E1 performance → Self-efficacy at E2	*B* = 0.01; CI(*SE*): [0.0004, 0.01] (0.003)
Grit → Strategy use at E1 → E1 performance → Self-efficacy at E2	*B* = 0.01; CI(*SE*): [0.0001, 0.02] (0.004)

Note. E1 = exam 1; E2 = exam 2. The results are significant if the CI does not contain 0. The non-significant indirect paths are in grey.

The second model examined the effect of the exam 2 SRL cycle on self-efficacy at exam 3. Unlike the first model, the mediation analyses revealed that there was a direct effect of grit on exam 3 self-efficacy, after accounting for the baseline of exam 2 self-efficacy, exam 2 constructive strategy use, exam 2 performance, and the other demographic and course covariates, $B = 0.18$, $p < .001$, CI(*SE*): [0.08, 0.29] (0.05). There were several indirect effects of grit on exam 3 self-efficacy although there were fewer indirect effects than the first model (Figure 16; Table 16). There were indirect effects of grit through (1) exam 2 self-efficacy and (2) exam 2 constructive strategy use. There were three indirect paths that were not significant (as indicated by the CI containing 0) in which the effect of grit on exam 3 self-efficacy did not indirectly go through: (1) exam 2 self-efficacy through exam 2 performance, (2) exam 2 constructive strategy use through exam 2 performance, or (3) exam 2 performance. These results revealed that the second SRL cycle had an effect on the self-efficacy for the third SRL cycle, supporting SRL theory. However, the effect of grit was different from the effects in the first model such that the indirect effects through exam performance did not replicate and there was a direct effect of grit on self-efficacy. In this case, grit explained additional variance beyond prior self-efficacy, cognitive study strategy use, exam performance for students' subsequent self-efficacy. Self-efficacy and constructive strategy use still explained some of this variance, but unlike the previous model, grit was explaining above and beyond these two proximal factors.

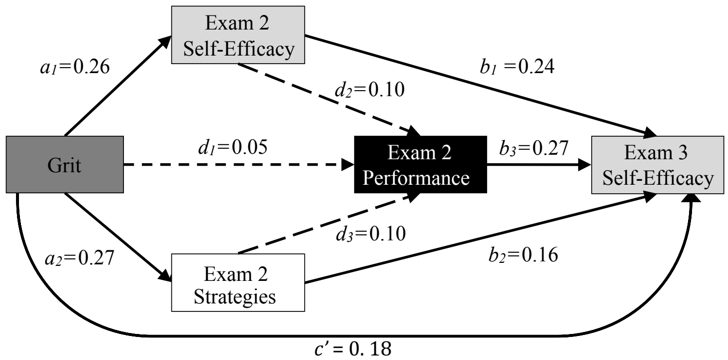


Figure 16. Mediation model for grit, exam 2 self-efficacy, exam 2 constructive strategies, exam 2 performance, and self-efficacy for exam 3, controlling for demographic and course variables. Black dashed lines indicate a non-significant relation.

Table 16. *Coefficients and inferential statistics for the indirect effects for the model depicted in Figure 16*

Indirect Effect Path	Coefficients and Inferential Statistics
Overall Indirect Effect	*B* = 0.13; CI(*SE*): [0.08, 0.20] (0.03)
Grit → Self-efficacy at E2→ Self-efficacy at E3	*B* = 0.06; CI(*SE*): [0.03, 0.11] (0.02)
Grit → Strategy use at E2→ Self-efficacy at E3	*B* = 0.04; CI(*SE*): [0.01, 0.09] (0.02)
Grit → E2 performance → Self-efficacy at E3	*B* = 0.01; CI(*SE*): [-0.02, 0.04] (0.02)
Grit → Self-efficacy at E2→ E2 performance → Self-efficacy at E3	*B* = 0.01; CI(*SE*): [-0.003, 0.02] (0.005)
Grit → Strategy use at E2→ E2 performance → Self-efficacy at E3	*B* = 0.01; CI(*SE*): [-0.002, 0.02] (0.006)

Note. E2 = exam 2; E3 = exam 3. The results are significant if the CI does not contain 0. The non-significant indirect paths are in grey.

3.7.7.2 Does the previous SRL cycle effect students' constructive strategy use_in the next SRL cycle? And does the previous SRL cycle explain the relation between grit and subsequent constructive strategy use?

Using the same approach as section 3.7.7.1, I evaluated whether the previous SRL cycles affected subsequent constructive strategy use. The first model evaluated the effect of the first cycle on exam 2 constructive strategy use (Figure 17). The second model evaluated the effect of the second cycle on exam 3 constructive strategy use (Figure 18). For each of the models, the regressions and model details are presented in Appendix C.3.

Mediation analyses revealed that there was not a direct effect of grit on exam 2 constructive strategy use, after accounting for the baseline of exam 1 self-efficacy, exam 1 constructive strategy use, exam 1 performance, and the other demographic and course covariates, $B = 0.06$; $p = 0.21$, CI(*SE*): [-0.04, 0.16] (0.05). There were several indirect effects of grit on exam 2 constructive strategy use (Figure 17; Table 17). There were indirect effects of grit through (1) exam 1 self-efficacy and (2) exam 1 constructive strategy use. There were three indirect effects that were not significant (as indicated by the CI's containing 0) in which the effect of grit on exam 2 constructive strategy use did not indirectly go through: (1) exam 1 self-efficacy through exam 1 performance, (2) exam 1 constructive strategy use through exam 1 performance, or (3) exam 1 performance. These results revealed that the first SRL cycle had an effect on the constructive strategy use for the second SRL cycle, supporting SRL theory. Moreover, the relation of grit on exam 2 constructive strategy use was explained by the contextually-dependent factors at the first exam, but not by exam performance. The next model evaluated whether the second SRL cycle had a similar effect on the third, and final SRL cycle.

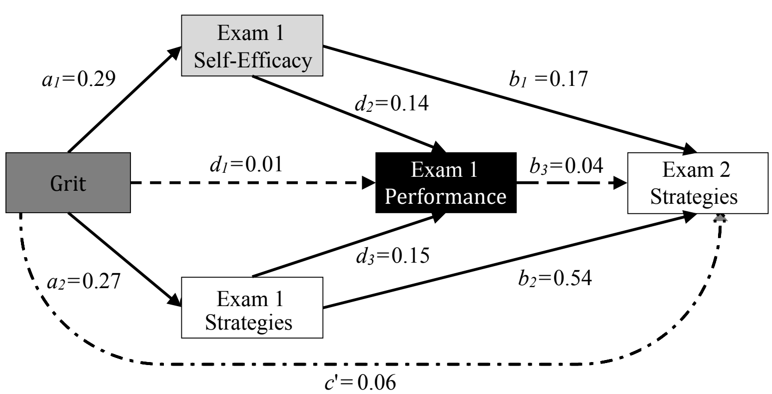


Figure 17. Mediation model for grit, exam 1 self-efficacy, exam 1 constructive strategies, exam 1 performance, and constructive strategies for exam 2, controlling for demographic and course variables. Black dashed lines indicate a non-significant relation

Table 17. *Coefficients and inferential statistics for the indirect effects for the model depicted in Figure 17*

Indirect Effect Path	Coefficients and Inferential Statistics
Overall Indirect Effect	*B* = 0.20; CI(*SE*): [0.12, 0.30] (0.05)
Grit → Self-efficacy at E1 → Strategy use at E2	*B* = 0.05; CI(*SE*): [0.02, 0.09] (0.02)
Grit → Strategy use at E1 → Strategy use at E2	*B* = 0.15; CI(*SE*): [0.08, 0.24] (0.04)
Grit → E1 performance → Strategy use at E2	*B* = 0.0004; CI(*SE*): [-0.004, 0.01] (0.004)
Grit → Self-efficacy at E1 → E1 performance → Strategy use at E2	*B* = 0.002; CI(*SE*): [-0.003, 0.01] (0.003)
Grit → Strategy use at E1 → E1 performance → Strategy use at E2	*B* = 0.002; CI(*SE*): [-0.003, 0.01] (0.003)

Note. E1 = exam 1; E2 = exam 2. The results are significant if the CI does not contain 0. The non-significant indirect paths are in grey.

The second model examined the effect of the exam 2 SRL cycle on constructive strategy use at exam 3. Like the first model, the mediation analyses revealed that there was not a direct effect of grit on exam 3 constructive strategy use, after accounting for the baseline of exam 2 self-efficacy, exam 2 constructive strategy use, exam 2 performance, and the other demographic and course covariates, B = 0.07, p =.05, CI(*SE*): [-0.03, 0.16] (0.05). There were two indirect effects of grit on exam 3 constructive strategy use (Figure 18; Table 18). There were indirect effects of grit through (1) exam 2 self-efficacy and (2) exam 2 constructive strategy use. There were three indirect paths that were not significant (as indicated by the CI containing 0) in which the effect of grit on exam 3 constructive strategy use did not indirectly go through: (1) exam 2 self-efficacy through exam 2 performance, (2) exam 2 constructive strategy use through exam 2 performance, or (3) exam 2 performance. These results revealed that the second SRL cycle had an effect on the constructive strategy use for the third SRL cycle, supporting SRL theory. It also replicated the previous pattern in which the contextually-dependent factors, the proximal factors, served as the mechanisms through which grit related to exam 3 constructive strategies.

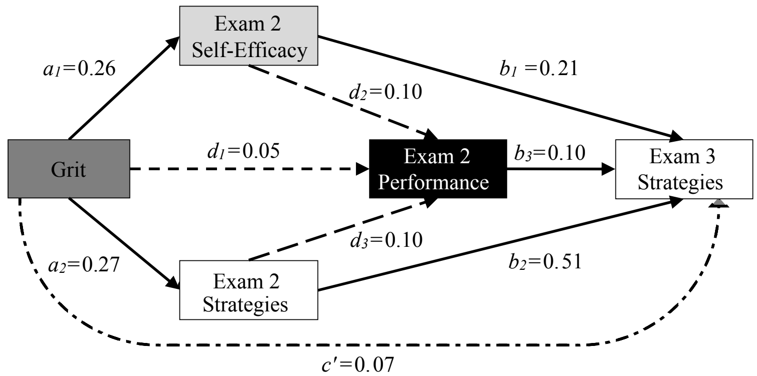


Figure 18. Mediation model for grit, exam 2 self-efficacy, exam 2 constructive strategies, exam 2 performance, and constructive strategy use for exam 3, controlling for demographic and course variables. Black dashed lines indicate a non-significant relation.

Table 18. *Coefficients and inferential statistics for the indirect effects for the model depicted in Figure 18*

Indirect Effect Path	Coefficients and Inferential Statistics
Overall Indirect Effect	*B* = 0.20; CI(*SE*): [0.12, 0.29] (0.04)
Grit → Self-efficacy at E2→ Strategy use at E3	*B* = 0.06; CI(*SE*): [0.02, 0.08] (0.02)
Grit → Strategy use at E2→ Strategy use at E3	*B* = 0.13; CI(*SE*): [0.06, 0.18] (0.04)
Grit → E2 performance → Strategy use at E3	*B* = 0.01; CI(*SE*): [-0.01, 0.02] (0.01)
Grit → Self-efficacy at E2→ E2 performance → Strategy use at E3	*B* = 0.003; CI(*SE*): [-0.001, 0.01] (0.002)
Grit → Strategy use at E2→ E2 performance → Strategy use at E3	*B* = 0.003; CI(*SE*): [-0.001, 0.01] (0.003)

Note. E2 = exam 2; E3 = exam 3. The results are significant if the CI does contain not 0. The non-significant indirect paths are in grey.

3.8 DISCUSSION

The purpose of this work was to examine how students self-regulate their learning over the course of a semester (see Figure 9). I approached this investigation by focusing on students' original grit for the course and the types of strategies, performances, and motivations students had at the beginning, middle, and end of a course. I also addressed several limitations to prior work investigating self-regulated learning by using different types of measures and a longitudinal design. Additionally, this work addressed the limited research examining the iterative nature of SRL models. In the next few sections, I discuss the results and their implications along with limitations and areas for future work.

3.8.1 Grit and study strategies

If students are gritty, then the more likely they are to persist and pursue their goals; one of which is presumably to perform well in the course. In order to efficiently perform well, students might be more likely to use constructive strategies that have been shown to promote robust learning. Although past work has shown that grit has been related to deliberate practice and has had a positive relation to the strategies students reported using, it was unclear whether this relation extended to certain types of study strategies, the number of study strategies, or students' change in strategy use. Using the distinctions as explained in Chapter 2, these study strategies were categorized as active or constructive. Grit was positively related to the number of constructive strategies for all three exams and the number of active strategies for exam 2.

Within these strategies, grit was consistently positively related to students reporting that they quizzed or tested themselves for each exam. Self-testing is a constructive strategy that provides immediate feedback as to whether a student knows or does not know the information. It is also challenging in that there are instances in which students cannot remember information or misremember information. However, practicing with quizzing also shows room for growth – students are able to evaluate what they "mastered" and what is still left to learn.

Grit was also positively associated with students reporting that they self-explained for exam 1 and with rewriting for exam 2. As shown in Chapter 2, more students reported self-explaining on the second and third exam. Therefore, it is possible that grittier students were already using self-explanation to study but as students progressed through the course other students that had lower grit were also learning to use self-explanation to study. This acquisition might be due to the instructional supports of the courses or because students were learning about memory and self-explanation in the course as those are two topics covered in Cognitive

Psychology. Rewriting had the opposite pattern, as it decreased. Fewer students reported using rewriting from the first to the second exam. It might be the case that grittier students were persistent in their strategy use and reluctant to change their approaches from the first to the second exam but then readjusted for the third exam.

Grit was consistently positively related to the number of constructive strategies and the use of constructive strategies as measured by the Likert-scale questionnaire for all three exams. These findings are consistent with prior work showing that grit has been related to a subset of the constructive strategies (Arslan et al., 2013; Wolters & Hussain, 2015). Along the way, grittier students may have learned how to employ different, more constructive strategies to persevere and obtain their learning and performance goals.

Based on prior work, it was unclear if grittier students would be persistent in their strategy use or overcome setbacks of lower grades by changing their strategies. Grit was not related to changes in strategy use, regardless if students did or did not perform well on the prior exam. This result should be interpreted cautiously as it is unclear how students changed their strategies. Students might have added strategies if they performed poorly on the prior exam or removed strategies if they performed well on the prior exam which could the alter the interpretation of these results. Future work could reframe the question into two to ask if students added or removed strategies since the previous exam. As previously mentioned, it could be that grittier students are more persistent in using the strategies that “work” for them and are less likely to adapt their strategy use.

3.8.2 Grit and self-efficacy

Another context dependent feature of SRL is self-efficacy. Both grit and self-efficacy share similar theoretical backgrounds (e.g., goal-oriented) and empirical findings (e.g., positively related to persistence, choosing challenging goals). Both constructs also have unique characteristics (e.g., grit is dispositional, and self-efficacy is a state), suggesting that the two constructs are differentiable but related. Replicating prior work (Wolters & Hussain, 2015), grit was positively related to student self-efficacy. This result replicated throughout the course. These findings suggest that grit and self-efficacy are related to one another and that this relation is robust across a semester.

3.8.3 Grit and performance

Prior work has found inconsistent relations between grit and performance. This study revealed consistent relations to exam performance. Grit predicted exam performance for exam 1 and exam 2 performance and was trending in that direction for exam 3, which is consistent with prior work showing that grit is positively related to GPA (e.g., Wolters & Hussain, 2015). Grit may have been related to the first two exams because it may have taken extra effort for students to figure out how to best study for those exams than for the third exam. Another alternative is that all students, regardless of their grit, were doing more to increase their performance at the third exam.

Another path to learning and performing well in a course is to manage one’s time effectively and attend lecture. Students that attended all the lectures had higher grit scores than students that missed more days than the two free days. These results are consistent with prior work illustrating that grittier students regulate their timing more efficiently (Bowman et al., 2015).

3.8.4 Testing the assumptions of SRL: Contextual mediators within one cycle

Grit might be related to these constructive study strategies, self-efficacy for the course, and exam performance, but what explains this relation? To answer this question, this work tested the mediations between grit and the contextual measures while also evaluating assumptions within SRL. These assumptions included: (1) that contextually-dependent factors should mediate dispositional measures and (2) that the iterative nature of SRL assumes that prior cycles should affect later cycles. One set of these mediation models evaluated whether the contextually-dependent measures (study strategies and self-efficacy) mediated the relation between grit and exam performance. Constructive study strategies and self-efficacy mediated the relation between grit and exam performance for all three exams, revealing that they serve as the mechanisms through which grit predicts exam performance. These results support SRL theory and reveal that the more local and adaptive constructs of self-regulated learning are the mechanisms through which grit is related to exam performance. For exam 2, the specific indirect paths for constructive study strategies and self-efficacy were not significant, although similar patterns as seen in the exam 1 and exam 3 models occurred. One explanation for this finding is that the contextual constraints of exam 2 taking place during “midterm” season in which students’ resources are spread across their courses, which might dampen the effect of grit. It could also be the case that at exam 2 students did not feel that exam 2 would be much of a challenge now that they experienced the first exam. In contrast, the first exam was their first challenge, and the third exam was their last challenge to perform well.

3.8.5 Testing the assumptions of SRL: Contextual mediators from one cycle to the next

The next set of mediation models evaluated whether the previous SRL cycle affected the later cycle. The models revealed that for both exam transitions the previous SRL factors (e.g., self-efficacy, constructive strategies, and exam performance) impacted the subsequent strategy use and self-efficacy. For both transitions the previous self-efficacy and constructive strategy use mediated the relation of grit on subsequent self-efficacy and constructive strategy use. Even though grit was related to these outcomes, these relations can be explained by the contributions from self-efficacy, constructive strategy use, and prior exam performance.

When examining subsequent self-efficacy, there were additional paths through which grit was related to self-efficacy. For both transitions there was an indirect path of grit on subsequent self-efficacy through prior strategy use and self-efficacy. Then, only for students' self-efficacy at exam 2, there was an indirect path of grit through prior exam 1 performance. In addition to supporting the cyclical assumption of SRL, this result also supports the theory of self-efficacy in that past experiences influence future self-efficacy. The model for the first transition (exam 1 to exam 2) was the only model (for both subsequent self-efficacy and constructive strategy use) in which prior exam performance played a role in mediating the relation of grit. For theory, this finding raises interesting questions about grit and when prior performance (and feedback from that performance) explains students' later adoptions of self-efficacy and constructive strategies. One answer might be that it depends on the situative aspects of college, such as the timing of exams (midterm season), and their relative performance in other courses (related courses or not).

Additionally, for self-efficacy at exam three, there was a direct path of grit on self-efficacy. Grit might be particularly important during the third exam compared to the first and second exam. At the third exam, students have their last attempt to maintain or improve their grade for the course. It is also a time in which winter break or summer is on the horizon. These two factors might make focusing on studying more difficult and more deliberate, suggesting that grit might be particularly important in this context. Perhaps grit provides more opportunities for students to engage in purposeful studying which contributes students' confidence in their abilities. In contrast, the additional opportunities for students to engage in purposeful studying, does not impact the constructive strategies they use – throughout this study and the prior, students were fairly consistent in their strategy use.

While the above explanation suggests that there are particular contexts in which grit is more important, another explanation is that there is a time interval between updating one's motivation. These results also suggest that grit and self-efficacy are more tightly related to each other than grit and constructive strategies (there was no direct effect of grit on constructive strategies at exam 3). Perhaps when the dispositional and context-dependent SRL measures are from a similar theoretical vein (e.g., grit and self-efficacy are both rooted in motivational theory around student goals), the dispositional measures are more likely to be related to the change in the contextual construct. However, when there is a mismatch between the dispositional and contextual measures (e.g., grit and study strategies) such that they are rooted in different overarching theories, then perhaps they are less likely to related to each other in later iterations of SRL.

3.8.6 Limitations and future work

One limitation of this work is that grit was assessed with three items, two of which that came from the consistency of interest subscale. Although the results in this work are consistent with both subscales in that grit presented in this work predicted similar outcomes as the effortful persistence subscale. Future work could use the entire short-scale to evaluate whether similar findings occur. Future work could also explore the actual behaviors of students. This work provided insight into the ways students perceived their study strategies, but that does not mean they were engaging in these actual behaviors. It is also unclear to what extent and when students were engaging in constructive study strategies. Perhaps indicators within a course management system would be one way to examine how students are behaviorally engaging in these strategies.

Additionally, college contexts have been shown to have grittier people (Duckworth et al., 2007). A broader distribution of grit scores might appear within other age-ranges and in other contexts. Whether these patterns replicate in those situations is an open question. Perhaps these relations would be stronger, as the theory suggests that people that are less gritty are less likely to put forth an effort to achieve their goals such as putting forth an effort to engage in constructive study strategies.

4.0 FOCUSING ON STUDENT BACKGROUNDS

Embedded within the definition of grit is that a challenge has to exist for the behaviors or activities of grit to emerge (Duckworth, 2016; Duckworth et al., 2007; Duckworth & Quinn, 2009). However, what is unclear is whether the amount of challenges a student faces reduces the application of grit to different situations. If a student encounters several challenges (compared to the average student), then she may, in turn, view herself as less gritty as she is constantly having to overcome or face a variety of challenges. Her grit is expended widely, potentially resulting in fewer resources for any one challenge. Within the college context, students from underrepresented backgrounds such as those with Black or Latinx ethnicities, face different institutional challenges than their White and Asian counterparts (Fischer, 2007, 2010; Hurtado et al., 2007; Locks, Hurtado, Bowman, & Oseguera, 2008). These additional challenges may result in their grittiness being spread thin. Additionally, there are a few studies that examine whether students from different ethnic backgrounds engage in SRL differently (Bembenutty, 2007). Therefore, in this chapter, I examined whether students' backgrounds moderated the effect of grit on the learning outcomes explored in the previous chapter. The methods and procedures in this chapter are identical to Chapter 3, but the analytical plan differs. Before diving into the analyses, I review prior literature that suggests that students from underrepresented backgrounds experience the college environment and grit differently than students from the majority.

4.1 GRIT WITH A SIDE OF PRIVLEDGE?

Within the literature, some studies have described ways to foster grit within students (e.g., (Mcglynn & Kelly, 2017; Polirstok, 2017) while others have fundamentally disagreed with the individual privilege that accompanies grit (Golden, 2017; Gorski, 2016; Schreiner, 2017; Stokas, 2015). Inherit in its definition, grit is the ability to work hard and chase one's goals. However, the attainability of those goals differs based on a person's privilege. As described by Schreiner (2017), you cannot pull yourself up by your bootstraps if you do not own boots. The peril of privilege is that those who are privileged are often unaware of their priveldge and blind to the struggles of others. For those that are privileged, they see how the system "works" and tend to assume that the system works for everyone. If the system is not working for someone, then they are not trying hard enough; they are not putting forth grit. The societal affordances or lack thereof can impact a student's grittiness.

Students from underrepresented ethnic backgrounds are more likely than the majority group to encounter a variety of academic, social, and financial challenges. For example, they tend to have lower GPAs, be first-generation college students, and have a lower average contribution of family and personal resources to fund college expenses (Bok & Bowen, 1998; Fischer, 2007). They are also more likely to have more negative perceptions of the racial climate on campus (Fischer, 2007) and to leave college (Bok & Bowen, 1998). Those who have negative encounters such as microaggressions are also less likely to persist (Cabrera, Nora, Terenzini, Pascarella, & Hagedorn, 1999; Hurtado, 1992). In addition to these social and financial challenges, students from underrepresented groups also encounter biases from educators. Prior work has shown that students encounter positive feedback bias in which educators provide minority students with less preferential and less constructive feedback than White students (Croft

& Schmader, 2012; Harber, 1998, 2004; Harber et al., 2012; Harber, Stafford, & Kennedy, 2010). Other challenges entail believing that they have to work harder to prove themselves, experiences with the imposter syndrome and encounters with microaggressions (Ewing, Richardson, James-Myers, & Russell, 1996; Peteet, Montgomery, & Weekes, 2015; Solorzano et al., 2000; Yosso et al., 2009).

Some scholars also pose that students from underrepresented backgrounds might be more skeptical of their educators and the institution based on these challenges and biases (Schunk & Zimmerman, 1994; Zusho, 2017). This skepticism might harm student motivation and performance as they may hesitate to invest in a course, an educator, or a college program in which they might face biased judgments or challenges to their identity. Some prior work supports this hypothesis in which college students from the underrepresented groups were shown to have lower final course grades and self-efficacy as compared to White students within a college course (Bembenutty, 2007). Thus, with grit increasingly receiving more interest and with universities determining ways to improve the college experience, it is critical to understand how and for whom do different constructs help, especially when students from underrepresented backgrounds are increasingly applying to college (and yet they still remain a minority group) (Perna, 2000) .

Very few studies have examined grit for students from underrepresented backgrounds. Strayhorn (2013) found that Black students with higher grit scores at predominately White institutions have higher high-school GPAs and college GPAs than Black students with lower grit scores. Akos and Kretchmar (2017) found that ethnic representation was negatively related to a subscale of grit (effortful persistence) such that students from underrepresented backgrounds had lower grit scores than students from majority groups. While the former results suggest that grit is related to similar findings as samples with predominately White students (e.g., Duckworth & Quinn, 2009), the latter finding provides evidence that students from minority backgrounds report lower grit scores. These latter results are consistent with Duckworth's commentary that perhaps, "the grittiest people are often the least willing to say they are gritty" (as cited in Powell, 2013). This limited research suggests that more work need to evaluate whether grit operates differently for students from different ethnic backgrounds.

Prior work examining the impact of grit on educational outcomes often controls for different backgrounds of students, which can be helpful in understanding the baseline of a construct, but it does not provide an understanding for how the construct functions for underrepresented groups within the sample. Not only do the majority of studies in psychological science focus on Western, educated, industrialized, rich and democratic aka "WEIRD" populations (Henrich et al., 2010; Jones, 2010), but those that do sample beyond the WEIRD population tend to control for demographic variables. In both prior studies examining student study strategies within the United States (Bowman et al., 2015; Wolters & Hussain, 2015), they controlled for the racial and ethnic backgrounds of students and did not evaluate whether there were differences. Therefore, it is unclear how grit operates for students from an underrepresented background that often face additional institutional barriers.

4.2 HYPOTHESES

Given the theoretical and limited empirical background, I hypothesized that students from underrepresented ethnic backgrounds would experience grit differently than students from the majority group. For students with an underrepresented ethnic background, they would have lower grit than students from the majority group. Grit might also not contribute to learning assessments for students from underrepresented backgrounds but would contribute to learning assessments for students from the majority group.

4.3 ANALYTICAL PLAN

First, I examined whether there were differences between the underrepresented and majority groups in their self-reports of grit, self-efficacy for cognitive psychology and constructive study strategy use, and their exam performance. Then, I examined whether student ethnic representation moderated the mediation of strategy use and self-efficacy on grit's relation to exam performance. To do so, I added a moderator to the mediation models presented in Chapter 3, Figure 14 for a total of three moderated mediation analyses, resulting in the PROCESS model 8. For all of the moderated mediation models, I used Hayes' (2018) model 8 with underrepresented/majority group as the moderator and self-efficacy for cognitive psychology and with constructive strategy use as parallel mediators for each exam. A 10,000 bootstrap method was also applied (Hayes, 2018). Effects coding was applied to class type (typical = - 0.5, scaffolded = 0.5), and sex (male = - 0.5, female = 0.5) to examine the models at baseline. These variables along with prior high school GPA and age were included as covariates for each of the models. The representation of students at the University of Pittsburgh was coded as majority (0, White and Asian) and underrepresented (1) in order to directly compare the two groups. Students that were considered underrepresented included those that identified as being Black, Latinx, Native American, or Pacific Islander. I also applied an HC3 estimator to better account for any homoscedastic errors in the estimation (Hayes & Cai, 2007). More details of these models and their interpretations are explained in detail below.

4.4 RESULTS

4.4.1 Descriptive statistics and comparisons

There were no differences between the two groups on the number of males and females, $X^2(1, N = 324) = 77$, $p = .38$, or in which course version they were enrolled in, $X^2(1, N = 324) = 2.08$, $p = .15$. Both types of students were of similar age (Underrepresented: $M = 20.62$, $SD = 1.05$; Represented: $M = 20.48$, $SD = 1.23$, $F(1,323) = 0.32$, $p = .57$, $d = 0.12$. Students from underrepresented backgrounds had lower high school GPA, $F(1,323) = 7.08$, $p = .008$, $d = 0.50$ (Underrepresented: $M = 3.71$, $SD = 0.49$; Represented: $M = 3.93$, $SD = 0.41$). There was a trend in which students from underrepresented backgrounds ($M = 3.19$, $SD = 0.69$) had slightly lower grit scores than students from represented backgrounds ($M = 3.42$, $SD = .64$), $F(1,323) = 3.08$, $p = .08$, $d = 0.34$. They also reported using fewer strategies for exam 1 and 2, and being less self-efficacious for exam 2, than students from represented backgrounds (Table 19). There was also a trend in which students from the underrepresented backgrounds performed lower on the first exam. There were no other differences between the two groups for study strategies, self-efficacy, or exam performance; see Table 19.

Table 19. *Descriptive and Inferential statistics for students from underrepresented and majority groups.*

Variable	Underrepresented *N*	*M*	*SD*	Majority *N*	*M*	*SD*	Inferential Statistic
Exam 1 Study Strategies	27	4.15	0.64	297	4.43	0.62	*F(1,323) = 4.89, p = .03, d = 0.44*
Exam 2 Study Strategies	27	4.16	0.62	297	4.41	0.59	*F(1,323) = 4.05, p = .04, d = 0.42*
Exam 3 Study Strategies	27	4.48	0.62	297	4.52	0.55	*F(1,323) = 0.14, p = .71, d = 0.07*
Exam 1 Self-Efficacy	27	4.27	0.75	297	4.35	0.63	*F(1,323) = 0.34, p =.56, d = 0.11*
Exam 2 Self-Efficacy	27	4.05	0.77	297	4.40	0.69	*F(1,323) = 6.35, p = .01, d = 0.48*
Exam 3 Self-Efficacy	27	4.41	0.70	297	4.53	0.70	*F(1,323) = 0.75, p = .39, d = 0.17*
Exam 1 Percent	27	80.53	8.79	297	83.65	8.25	*F*(1,323) = 3.50, *p* = .06, *d* = 0.37
Exam 2 Percent	27	80.00	7.22	297	82.52	10.12	*t*(36.02) = 1.67, *p* = .10, *d* = 0.29
Exam 3 Percent	27	82.12	7.54	297	84.32	8.97	*F*(1,323) = 1.53, *p* = .22, *d* = 0.27

4.4.2 Moderated mediations

To evaluate whether the relations between grit and exam performance through self-efficacy and constructive strategy use differed based on students' representation, I applied a moderated mediation analysis to each exam. PROCESS model 8 produces three regressions (Appendix D). Model 8 is the same model as model 4 in the previous chapter, but model 8 also includes the moderator and the interaction term between the moderator and grit for each of the three regressions (compare Figure 14 to 19). For example, for the model at exam 1, the first regression regresses grit on exam 1 self-efficacy with the group variable and the interaction between the group variable and grit along with the inclusion of the covariates. The second regresses grit on exam 1 constructive strategy use with the group variable and the interaction between the group variable and grit along with the inclusion of the covariates. The third regression regresses all of the variables on exam 1 performance. For each model, I reported the direct and indirect effects of grit on the respective exam performance and the index of moderated mediations. The index of moderated mediation equates to the difference between the two indirect effects for each of the moderating variables (underrepresented group and the majority group). If the index of moderated mediation (the interval estimate of the parameter of a function linking the indirect effect to the moderator) is significant (e.g., the CI does not contain 0), then the indirect effect depends on the moderator – the mediation is moderated. A negative index indicates that the indirect effect is negatively related to the moderator. In this case, the indirect effect does not exist for students from the underrepresented group. For a discussion on the index of moderated mediation, see Hayes (2015). All continuous variables were standardized such that the coefficients represent the change in the number of standard deviations above or below the means. All coefficients and model details are presented as tables in Appendix D.

For the first exam, a moderated mediation analysis revealed that there were no direct effects of grit on exam 1 performance for either group (Table 20, Appendix D), which mirrors the results found in the previous chapter. There was a trend toward a moderated mediation through self-efficacy such that there was an indirect effect of grit on exam 1 performance through self-efficacy for the majority group, but this relation did not exist for the underrepresented group. There was also a trend toward a moderated mediation through constructive strategy use such that there was an indirect effect of grit on exam 1 performance through strategy use for the majority group, but this relation did not exist for the underrepresented group. These results suggest that grit may not play a central role in student performance for students from underrepresented backgrounds during the initial SRL cycle.

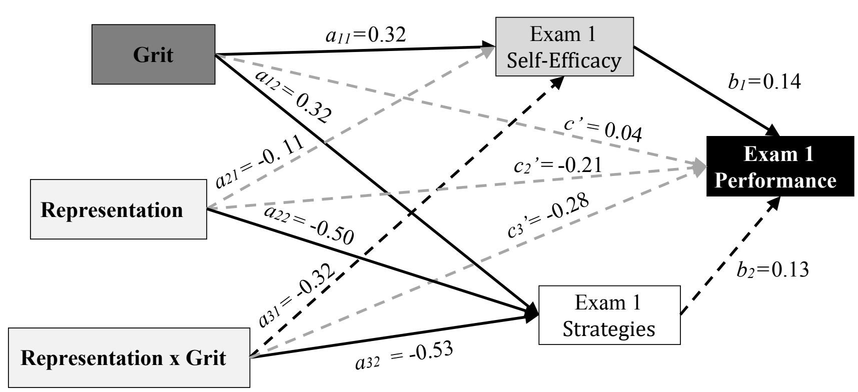


Figure 19. Moderated mediation for exam 1 performance. Black dashed lines indicate a marginal relation. Grey dashed lines indicate a non-significant relation. All coefficients for this model are represented in Appendix D.

Table 20. *Summary of direct, indirect, and index of moderated mediation for grit, self-efficacy for cognitive psychology, constructive strategy use, and exam performance.*

	Conditional Effect Type	Group	*B*	*SE*	LLCI	ULCI
Exam 1 Performance	Direct Effects	Majority	0.04	0.06	[-0.08,	0.16]
		Underrepresented	-0.24	0.21	[-0.65,	0.17]
	Indirect Effects via Self-Efficacy	Majority	0.05	0.02	[0.01,	0.08]
		Underrepresented	-0.0002	0.03	[-0.05,	0.06]
		Index of Moderated Mediation	-0.05	0.03	[-0.12,	0.01]
	Indirect Effects via Strategy Use	Majority	0.04	0.02	[0.002,	0.10]
		Underrepresented	-0.03	0.04	[-0.11,	0.04]
		Index of Moderated Mediation	-0.07	0.05	[-0.19,	0.004]
Exam 2 Performance	Direct Effects	Majority	0.03	0.06	[-0.09,	0.15]
		Underrepresented	0.21	0.12	[-0.03,	0.45]
	Indirect Effects via Self-Efficacy	Majority	0.03	0.02	[-0.01,	0.08]
		Underrepresented	-0.003	0.02	[-0.06,	0.04]
		Index of Moderated Mediation	-0.03	0.03	[-0.12,	0.01]
	Indirect Effects via Strategy Use	Majority	0.03	0.02	[-0.009,	0.08]
		Underrepresented	0.01	0.03	[-0.06,	0.07]
		Index of Moderated Mediation	-0.02	0.04	[-0.11,	0.03]
Exam 3 Performance	Direct Effects	Majority	0.01	0.06	[-0.11,	0.13]
		Underrepresented	-0.11	0.17	[-0.45,	0.23]
	Indirect Effects via Self-Efficacy	Majority	0.04	0.02	[0.01,	0.09]
		Underrepresented	0.064	0.04	[0.004,	0.15]
		Index of Moderated Mediation	0.02	0.03	[-0.03,	0.09]
	Indirect Effects via Strategy Use	Majority	0.04	0.02	[0.001,	0.08]
		Underrepresented	-0.01	0.03	[-0.09,	0.04]
		Index of Moderated Mediation	-0.67	0.60	[-2.13,	0.11]

Note. The results are significant if the CI does not contain 0. The non-significant indirect paths are in grey. LLCI = lower level confidence interval. ULCI = upper level confidence interval.

For the second exam, a different pattern emerged. The moderated mediation analysis revealed that there were no indirect or direct effects of grit on exam 2 performance for students in the underrepresented and majority groups (Table 20). When accounting for baseline self-efficacy and strategy use, grit was no longer related to exam 2 performance for either group (Figure 20).

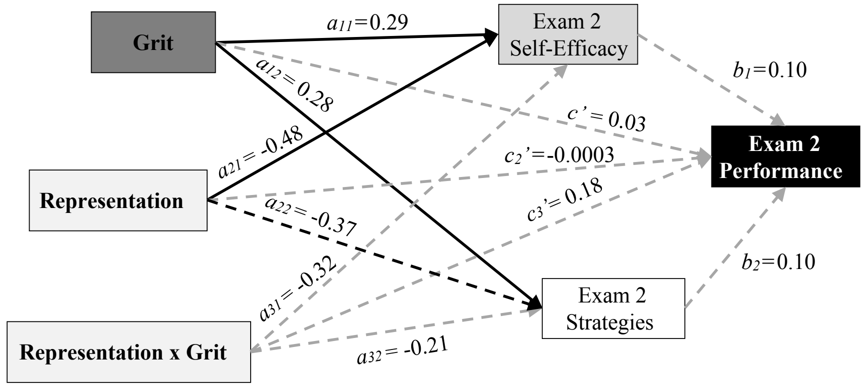


Figure 20. Moderated mediation for exam 2 performance. Black dashed lines indicate a marginal relation. Grey dashed lines indicate a non-significant relation. All coefficients for this model are represented in Appendix D.

The moderated mediation analysis for the third exam also revealed a different pattern. The results revealed that there were no direct effects of grit on exam 3 performance for either group (Table 20, Figure 21, Appendix D). There was no moderated mediation through self-efficacy such that for both groups there was an indirect effect of grit on exam 3 performance through self-efficacy. There was a trend toward a moderated mediation through constructive strategy use such that there was an indirect effect of grit on exam 3 performance through strategy use for the majority group, but this relation did not exist for the underrepresented group. As in the first exam, these results suggest that grit may not play a central role in student performance for students from underrepresented backgrounds.

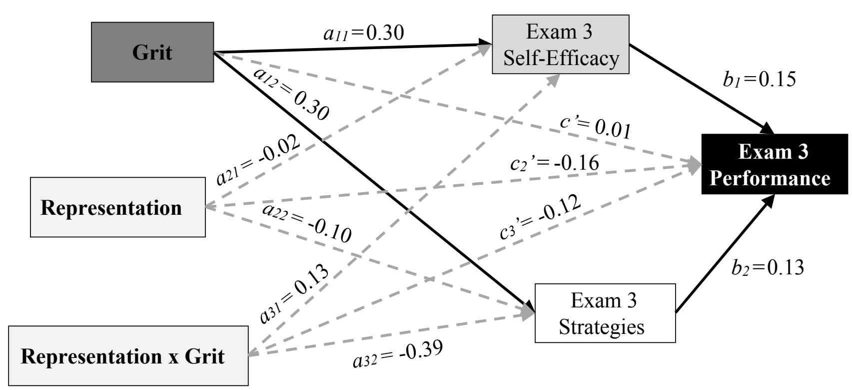


Figure 21. Moderated mediation for exam 3 performance. Grey dashed lines indicate a non-significant relation. All coefficients for this model are represented in Appendix D.

4.5 DISCUSSION

There is much debate about the contributions and emphasis of encouraging students to be grittier (Golden, 2017; Mcglynn & Kelly, 2017; Polirstok, 2017; Schreiner, 2017). Overcoming a challenge and failures can productively result in beneficial learning outcomes within set parameters (e.g., desirable difficulties, McDaniel & Butler, 2011; productive failure, Kapur & Bielaczyc, 2012), but overcoming constant challenges to one's identity can be taxing and result in other unnecessary obstacles (e.g., issues with physical and mental health, Nadal, Griffin, Wong, Hamit, & Rasmus, 2014). Therefore, in this chapter, I examined whether students from underrepresented ethnic backgrounds experienced grit differently than their majority counterparts. Although prior work warns against emphasizing grit, is there evidence to support this caution? No prior work has explicitly examined grit and its relation to learning strategies, self-efficacy, and exam performance with a focus on student ethnic backgrounds.

Initial analyses revealed that students from underrepresented backgrounds had lower high school GPAs, endorsed using fewer study strategies for the first and second exam, had lower self-efficacy for exam 3. There were also trends in which they had lower grit scores, which is consistent with Akos and Kretchmar (2017), and lower exam 1 scores. These results show that there is a gap between students from underrepresented and represented ethnic backgrounds in components of SRL in college contexts. This finding suggests that student from underrepresented backgrounds are not receiving adequate instructional support and preparation.

The results from this study also suggest that there are some cases in which grit may operate differently for students from underrepresented backgrounds than students from represented backgrounds. The moderated mediation models examining the mediation of grit on exam performance revealed that for the first exam there is a trend in which grit did not play a role in student performance for students from underrepresented backgrounds, but it did play a role for students from the majority group. This moderated difference was not significant at exam 2, but at exam 3 there was a similar trend in which strategy use did not explain the effect of grit on exam performance. Taken together, these results suggest that grit may be operating differently for students from underrepresented and majority backgrounds. These different patterns might be attributed to the amount of institutional challenges students face and/or the level to which students employ constructive strategies and are self-efficacious.

Another explanation for these findings is that grit is not being adequately measured for students from underrepresented backgrounds. Students from underrepresented backgrounds might be perceiving and/or interpreting the grit items differently than represented students. If underrepresented students constantly have to be gritty, then their *actual* level of grit might be substantially higher than represented students. These higher levels might skew their perception of what it means to be gritty so that when reporting their grit, underrepresented students might be reporting their grit on a different scale than represented students. The current measure might not be accurately capturing grit for students from underrepresented backgrounds such that their responses are shifted down the scale. Future work could explore the psychometric properties of the scale for these different groups. Future work could also explore this possibility by examining how students interpret these measures and compare those interpretations to a behavioral measure of grit. It might also be the case that we did not have enough power to assess these differences as the underrepresented group was only 8% of the total sample (a representative sample of students from underrepresented groups).

4.5.1 A cautionary tale

The scope of this chapter was to examine the differences between students from different ethnic backgrounds. Due to the population of students at the University of Pittsburgh, there are not many underrepresented students making it difficult to adequately sample students. However, this work suggests that emphasizing grit may not necessarily be beneficial for students from underrepresented backgrounds. This work also revealed that at a contextually dependent level, there is a gap between students' study strategies and self-efficacy throughout a course which may also relate to differences in the achievement gap. Therefore, it might best serve students if instructors employ instructional activities that boost students' use of constructive study strategies and self-efficacy within their courses to alleviate this disparity.

5.0 CONCLUSIONS

Although examining instructional techniques to promote student learning has been a productive field in cognitive psychology (Koedinger et al., 2013, 2012), more work needs to focus on understanding how to integrate those techniques into students' existing beliefs about how they study as well as their motivations for studying. Therefore, the theme of this work was to understand how and for whom do aspects of SRL operate within the college classroom. Clarifying student perceptions and understanding how those perceptions function within different types of instructional supports may enhance the likelihood of students acquiring robust knowledge that transcends past the course – that is the goal of education after all.

Importantly, this work employed two types of measures – an open-ended question about studying and strategy-specific questions. Each measure had its own set of advantages and disadvantages. The open-ended questions provided insight into which study techniques students were aware of without being prompted about a specific strategy. This measure also had its drawbacks as it took a long time to reliably code the data for the different strategies. In contrast, the strategy-specific questions (forced-choice and Likert-scale) took less time to code, but also provided additional opportunities for students to falsely report that they used a strategy. For example, even though students were asked to respond to the questions for the current exam and the specific course, students might be more likely to say they used the strategy if they think the strategy is important. For both measures, there is also the possibility that students might report on how they generally use the strategy. Using both measures provided a complementary and more in-depth analysis of how students perceived their studying process.

In the second chapter, students metacognitive study strategies revealed important information about how students believed they studied and about the aspects of studying that were salient to them. For similar courses, this work can serve as a baseline with which instructors could identify areas to intervene with their students. Providing additional scaffolds that support self-explanation, analogical comparison, metacognitive monitoring and regulation, and spreading out studying might be potential areas to focus on as they were positively related to exam performance. There has been some work suggesting that when students read and discuss research articles about the cognitive strategies, it increases their beliefs that the strategy is more effective (McCabe, 2011); whether or not students use those strategies is still open for exploration.

In the third chapter, I evaluated a subset of these strategies and their role in the cyclical process of SRL throughout a course. Evaluating SRL at multiple time points allowed for an in-depth view of how students believed they engaged with a course. By examining the iterative cycles of SRL, it also revealed which aspects of an SRL cycle carry over into the next iteration. The combination of these results provide evidence that grit may be a general indicator for student’s course self-efficacy and strategies students use, but the context-dependent measures reveal a more accurate picture and explain the relation between grit on exam performance, strategy use, and self-efficacy. These context-dependent measures are also more easily supported in the classroom as it is easier to change a state-like aspect than a trait-like characteristic.

In the fourth chapter, I addressed the for whom question by examining whether there was a difference in SRL between students from an underrepresented ethnic background and the majority. Throughout various points in the course, students from underrepresented backgrounds reported using few study strategies, being less self-efficacious and performed worse on the first exam than the majority. These students also tended to endorse lower grit scores. There were also trends in which study strategies or self-efficacy did not explain the relation between grit and exam performance for the underrepresented group. If Chapter 2 and 3 were not convincing that students could use additional instructional supports to improve their learning and motivation, then these findings should be.

5.1 THEORETICAL IMPLICATIONS

Theoretically, this work provides insights for researchers from several different strands of research. Results from the second chapter supported the ICAP hypothesis in that more constructive strategies were positively related to exam performance. This work was the first extension of the ICAP hypothesis to students' self-reports of their overt behaviors. Further, this relation replicated for all the exams.

Results from the third and fourth chapters revealed exciting findings for both self-regulated learning research and grit theorists. The third chapter revealed that the relation of grit on exam performance was mediated by constructive strategies and self-efficacy, supporting the assumption of self-regulated learning and revealing that grit is related to these aspects. Chapter 3 also revealed that for the majority of the transitions grit was not directly related to self-efficacy and constructive strategies that occurred in the next cycle. Grit was only directly related to self-efficacy on the third exam (a particularly time-sensitive period). Given the limited amount of empirical work investigating grit within self-regulated learning, theorists might not be surprised by these findings. The theoretical overlap between self-efficacy and grit suggests that they might be likely to be related. However, what is interesting for theory is that there might be particular contexts and situations when these relations emerge. Is there a time-lag for when grit and self-efficacy will be related above and beyond prior exam performance, self-efficacy, and constructive strategy use? Or is there a situational demand?

In contrast to Chapter 2 and 3, Chapter 4 might be particularly surprising for self-regulated learning and grit theory. Not much work in either self-regulated learning or grit has examined students from underrepresented backgrounds. Underrepresented students were experiencing lower reports of self-efficacy, constructive strategies, grit, and exam performance (the latter two trending) at some point throughout the semester. These lower reports suggest that student background variables are critical to include and examine for these theories. The additional finding that there were trends in which grit was not directly or indirectly related to exam performance when including self-efficacy and constructive strategy use, for underrepresented students (whereas it was indirectly related for represented students) indicates that grit is functioning differently for underrepresented students. Because ethnic minority groups have rarely been examined within these theoretical lenses, I urge for more work to consider different populations and examine these differences to have a better understanding of the conditions and parameters of theory.

5.2 PRACTICAL IMPLICATIONS

Based on this work, there are clearly some instructional supports that should be implemented within the college classroom. Constructive strategies and self-efficacy consistently related to exam performance and students from underrepresented backgrounds were sometimes lower in these areas. To support these aspects, instructors could structure their courses to integrate different learning activities that support the use of the constructive strategies, which promote robust learning (see Chi, 2009; Chi & Wylie, 2014 and Koedinger et al., 2013, 2012). Supporting constructive strategies might have incremental benefits as past work has shown that these strategies improve student understanding and learning, which might also help increase students' confidence in their abilities to do well in a course (their self-efficacy). Other instructional supports might include those that focus on supporting students' self-efficacy, such as employing self-talk, modeling growth, and opportunities to improve throughout the course (see Askell-Williams, Lawson, & Skrzypiec, 2012, Bembenutty, 2009, and Weinstein, Husman, & Dierking, 2000). The effectiveness and utility of these different supports may depend on how the supports are implemented, the type of course, and the situative factors within the larger learning environment. Understanding how motivation and study strategies work together from a theoretical and practical level are critical when determining how to improve student learning.

APPENDIX A

ASPECTS OF STUDYING: STUDY STRATEGIES, RESOURCES, AND TIMING

A.1 OPEN-ENDED ASPECTS OF STUDYING CODING PROTOCOL

The open-ended protocol was developed by reading through a subset of students' reports and evaluating whether there was evidence for that study strategy, resource, or time management component. Some strategies (e.g., rereading and metacognitive regulation) were not readily evident or clearly definable given the ways in which students described aspects of their studying. Then formal codes were developed for each of the strategies, resources, and time management components. Two coders separately coded the data. Then a Kappa was calculated to evaluate the interrater reliability. This process went through a few iterations with revisions to the coding protocol until the coders were able to reliable code the data.

To code the data, coders were instructed to read the statement and categorize a subset of the codes as one time (e.g., code the study strategies together and then on a later iteration code the resources) to help the coder stay in the frame of the specific type of study approach. Coders were also instructed to code and then to go through the data again to confirm their codes. Table 21 contains the coding protocol, and Table 22 contains examples of students' responses to the open-ended question. Students generated an average of 79.39 (*SD* = 45.78, Min = 6, Max = 256), 61.95 (*SD* = 41.35, Min = 1, Max = 251), 54.79 (*SD* = 39.74, Min = 2, Max = 251), words per exam, respectively, to describe their approach to studying. The number of words students wrote in response to the open-ended question was positively related to the respective exam performance, after controlling for the demographic and course variables (Exam 1: $r_t = .11$, $p = .002$, Exam 2: $r_t = .14$, $p < .001$, Exam 3: $r_t = .19$, $p < .001$).

Table 21. *Coding protocol.*

Aspect	Strategy	Students mentioned…
Study Strategies	Rewriting	rewriting their notes or study guide regardless of how much they rewrote
	Highlighting	highlighting concepts
	Summarizing	summarizing anything including textbook, notes, study guide.
	Quizzing	quizzing themselves using the resources we provide or their own resources
	Examples	creating their own examples
	Analogical comparison	comparing or contrasting concepts
	Self-explanations	explaining concepts/topics to themselves
	Monitoring	keeping track of their awareness of their understanding, checking to see when they did or did not know something
Resources	Notes	reading/reviewing/using the notes (including lecture slides, outlines, notes on the book) at all regardless if they used them to fill out their study guide or not
	Book sections	reading/reviewing/using the book sections regardless of what for, students have to specify that the only used parts of the book
	Entire book	reading/reviewing/using the book or chapters regardless of what for
	Study guide	completing or using the study guide we provided
	Practice test*	reviewing/using/completing the practice test (only given for exam 1)
	Note Card	creating their crib notes
	Created a resource	creating their own resource such as a chart, concept map, study guide, flash cards
	Activities	reading/reviewing/using the in-class activities
	Internet	reading/using the internet in any form to help them
	Group	working in a group to study
	Office hours	attending office hours
Time	Throughout	studying weeks leading up to the exam/throughout the semester
	A few days	studying the week or a few days before the exam
	Crammed	cramming the day before the exam
	Didn't study	that they didn't study

Table 22. *Examples of student responses to the open-ended question.*

Student	Response
Student 1	"Just went through the textbook with the study guide and reviewed my notes"
Student 2	"I reviewed my notes, then reviewed the lecture slides and wrote down summaries to each section. Then I completed the study guide by writing answers next to each question. Finally, I chose the most important points and things I could confuse and wrote them on my notecard."
Student 3	"I read the textbook and took notes. I also reviewed my notes and went over some parts I wasn't clear about with a friend. I would read a section of the textbook and write down parts I thought would be harder to understand or things I thought would be important. There were some concepts that I wasn't sure about so I reviewed over those with a friend."
Student 4	"I created an outline of information that i would need to know based on what was written on the study guide. I then reviewed my outline multiple times and talked out loud some of the concepts that were more difficult to understand. By explaining them out loud to myself, I was able to comprehend and get a better grasp on some of the more difficult concepts. I reviewed my outline again and filled in my crib note card based on some concepts/ideas/vocabulary that i was not 100% confident in."
Student 5	"The only way I really know how to successfully study for an exam is to make notecards. In doing this, I collect all of my notes from the textbook readings and lectures and write each term/topic and their explanation on a 4x6 index card. I then compared these notes with the study guide to make sure that I am hitting all of the core topics listed and that I can explain them and/or easily find the notecard that explains them. I make additions to the appropriate section of notecards if I missed something mentioned on the study guide that was not clearly mentioned in my notes. I find that rewriting all of the information and physically separating it into different topics (by writing on separate notecards) helps me conceptualize and better learn the information. I review this stack of notecards in total at least twice. I put a lot of information on each notecard, so I don't necessarily try to "quiz" myself on them and they certainly don't function as "flashcards," but I will read through each card thoroughly numerous times to further embed the information in my brain. I started making the notecards a week in advance, and once they were finished, I reviewed the complete stack at least once a day until the exam. For this exam specifically, I also made a separate crib notes card (on a regular 3x5 index card) with general information and information that I had a difficult time remembering. I did this after going through my notecards, so I knew which topics were harder for me to grasp."

A.2 NUMBER AND PERCENTAGES OF STUDENTS THAT REPORTED USING STRATEGIES IN THE OPEN-ENDED RESPONSE

Table 23. *Descriptive statistics for the open-ended strategies.*

Strategy Approach	Type	Exam 1		Exam 2		Exam 3		Averaged Across Exams	
		N	%	*N*	%	*N*	%	*N*	%
Study Strategies	Rewrote	86	26%	36	11%	40	12%	54.00	16%
	Highlighted	45	14%	46	14%	37	11%	42.67	13%
	Summarized	19	6%	11	3%	12	4%	14.00	4%
	Quizzed Themselves	92	28%	52	16%	46	14%	63.33	19%
	Created Examples	16	5%	13	4%	14	4%	14.33	4%
	Analogically Compared	23	7%	35	11%	17	5%	25.00	8%
	Self-Explained	29	9%	47	14%	41	12%	39.00	12%
	Monitoring	205	62%	187	57%	172	52%	188.00	57%
	Min Number of Strategies	*0*	---	*0*	---	*0*	---	*0*	---
	Max Number of Strategies	*5*	---	*6*	---	*4*	---	*6*	---
	Average Number	*1.56*	---	*1.29*	---	*1.15*	---	*1.33*	---
Resources	Notes	303	92%	306	93%	302	92%	303.67	92%
	Book Section	175	53%	135	41%	120	36%	143.33	43%
	Book	106	32%	102	31%	75	23%	94.33	29%
	Study Guide	252	76%	239	72%	251	76%	247.33	75%
	Activities	17	5%	13	4%	17	5%	15.67	5%
	Practice Test*	56	17%						
	Note Card	65	20%	65	20%	57	17%	62.33	19%
	Created a Resource	109	33%	71	22%	70	21%	83.33	25%
	Internet	35	11%	23	7%	16	5%	24.67	7%
	Group	52	16%	57	17%	54	16%	54.33	16%
	Office Hours	6	2%	2	1%	2	1%	3.33	1%
	Min Number of Strategies	*0*	---	*0*	---	*0*	---	*0*	---
	Max Number of Strategies	*9*	---	*6*	---	*7*	---	*9*	---
	Average Number	*3.56*	---	*3.07*	---	*2.92*	---	*3.18*	---
Time Management	Throughout	31	9%	19	6%	14	4%	21.33	6%
	A Few Days Before	31	9%	18	5%	23	7%	24.00	7%
	Crammed	1	0%	3	1%	2	1%	2.00	1%
	Didn't Study	0	0%	0	0%	0	0%	0	0%
	Min Number of Strategies	*0*	---	*0*	---	*0*	---	*0*	---
	Max Number of Strategies	*1*	---	*2*	---	*2*	---	*1*	---
	Average Number	*0.19*	---	*0.12*	---	*0.33*	---	*0.21*	---

A.3 CHANGES IN OPEN-ENDED STRATEGIES ACROSS THE EXAMS

In addition to examining the number of exams students reported using a strategy for each exam. I also examined how students changed their responses in their open-ended responses. Between each exam, students could have been added, removed, consistently used, or consistently not use study strategies. Across all the exams, their responses could have been consistently not present, removed after the first exam, added at exam 2 and then removed at exam 3, removed at exam 3, removed at exam 2 and then added back at exam 3, added at exam 3, added at exam 2 and then kept for exam 3, or consistently present. These different changes are in Figure 22 for study strategies, Figure 23 for resources, and Figure 24 for timing. Monitoring one's understanding, the book, sections of the book, the study guide, and created resources had the most variation across the exams.

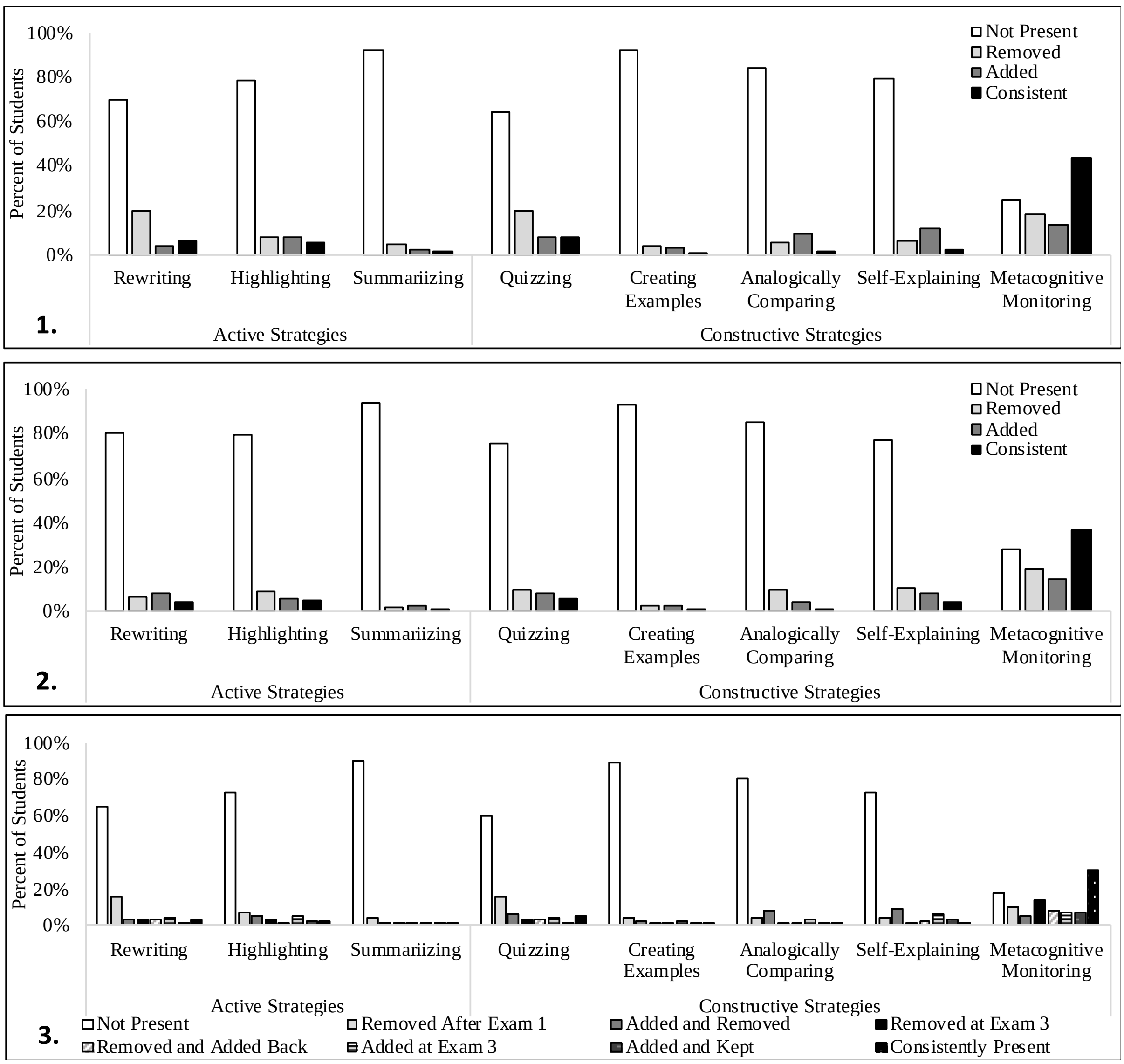


Figure 22. Percent of students that changed their study strategies (1) from exam 1 to exam 2, (2) from exam 2 to exam 3, and (3) across all the exams

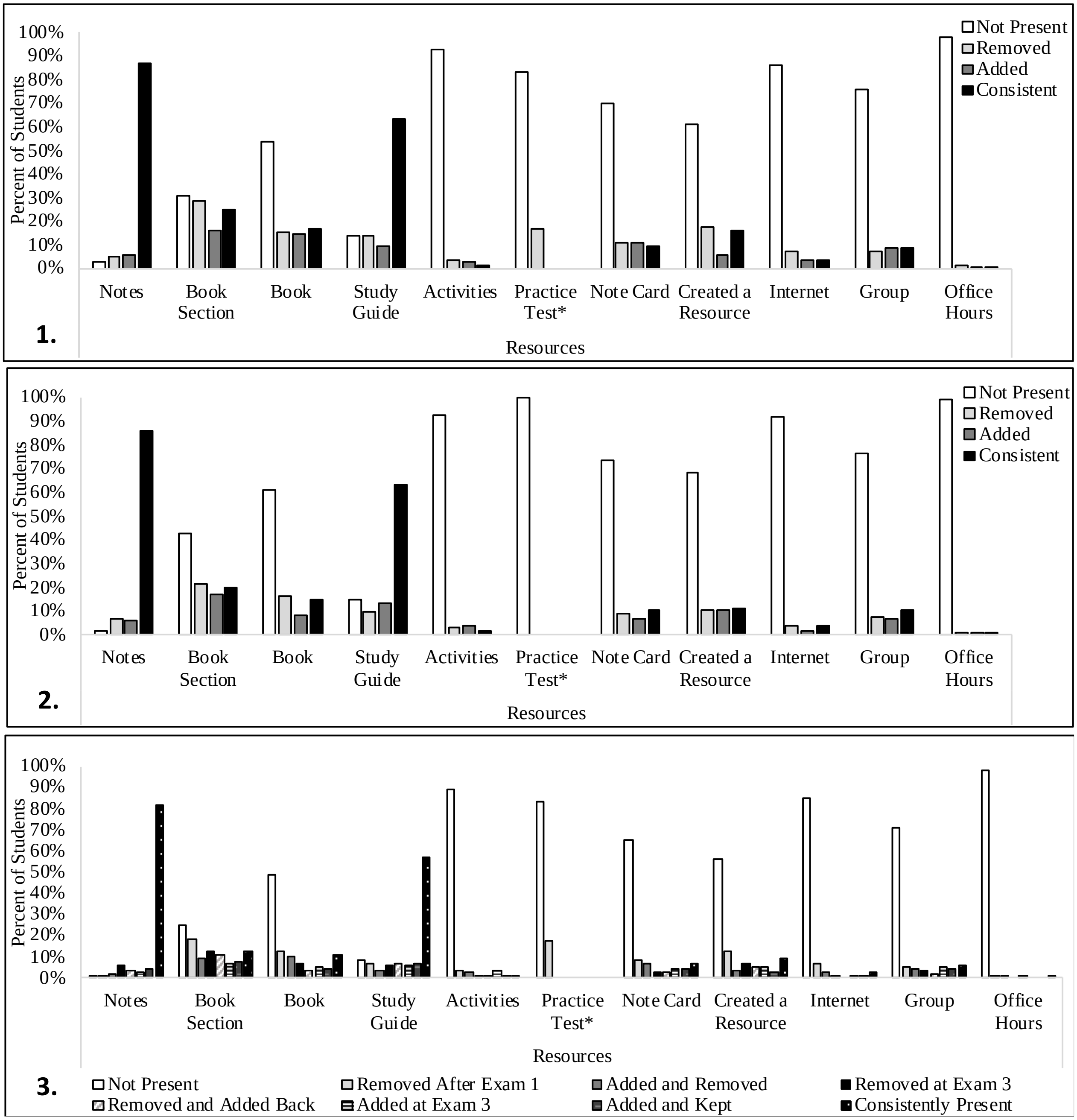


Figure 23. Percent of students that changed their resources (1) from exam 1 to exam 2, (2) from exam 2 to exam 3, and (3) across all the exams

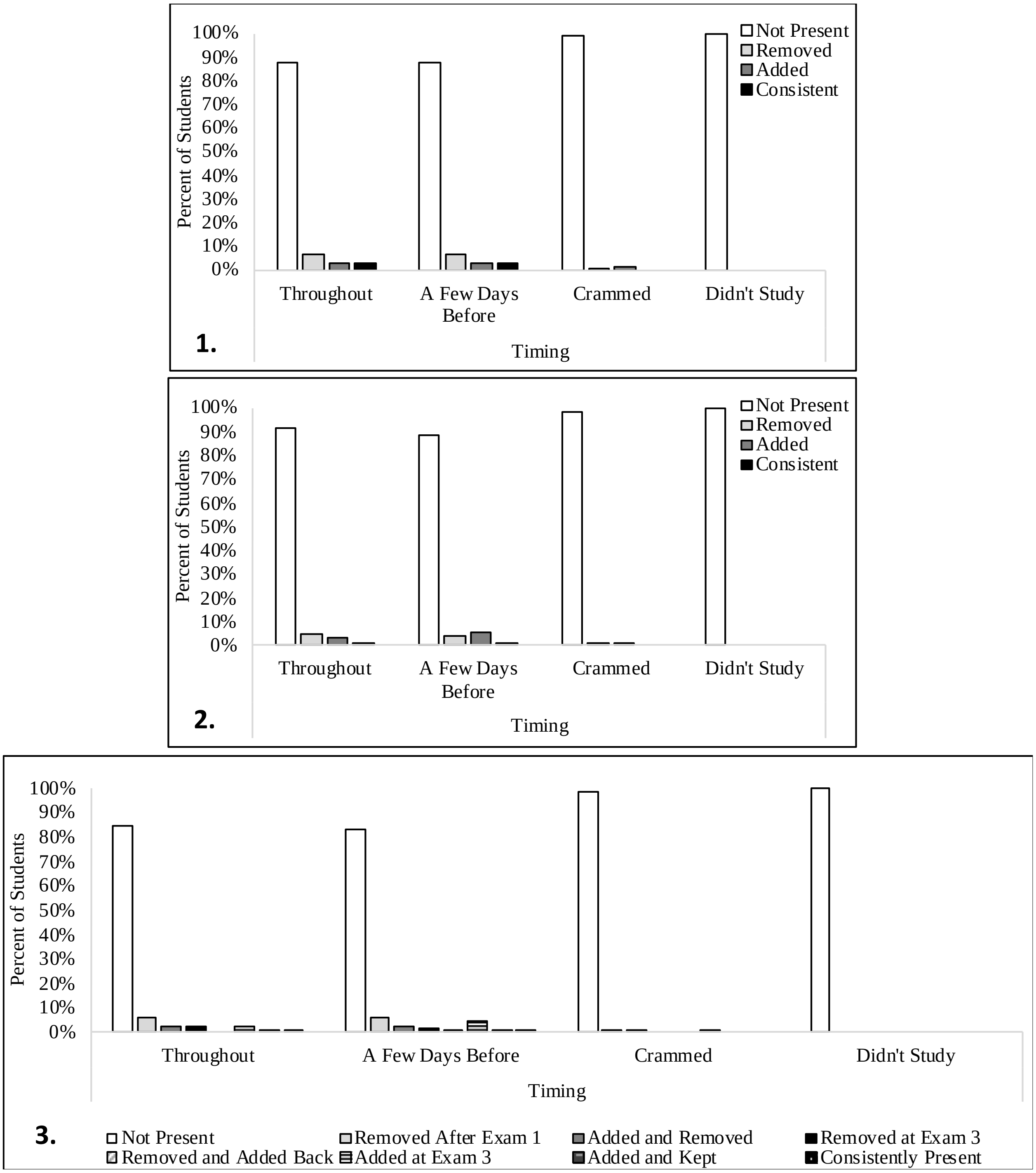


Figure 24. Percent of students that changed timing (1) from exam 1 to exam 2, (2) from exam 2 to exam 3, and (3) across all the exams

A.4 RELIABILITY CHANGE INDEX FOR LIKERT-SCALE STRATEGIES

In addition to the global change, I also examined whether the patterns across exams in the ways students increased, decreased, or maintained their endorsements of the Likert-scale questions by examining their RCI (Figure 25).

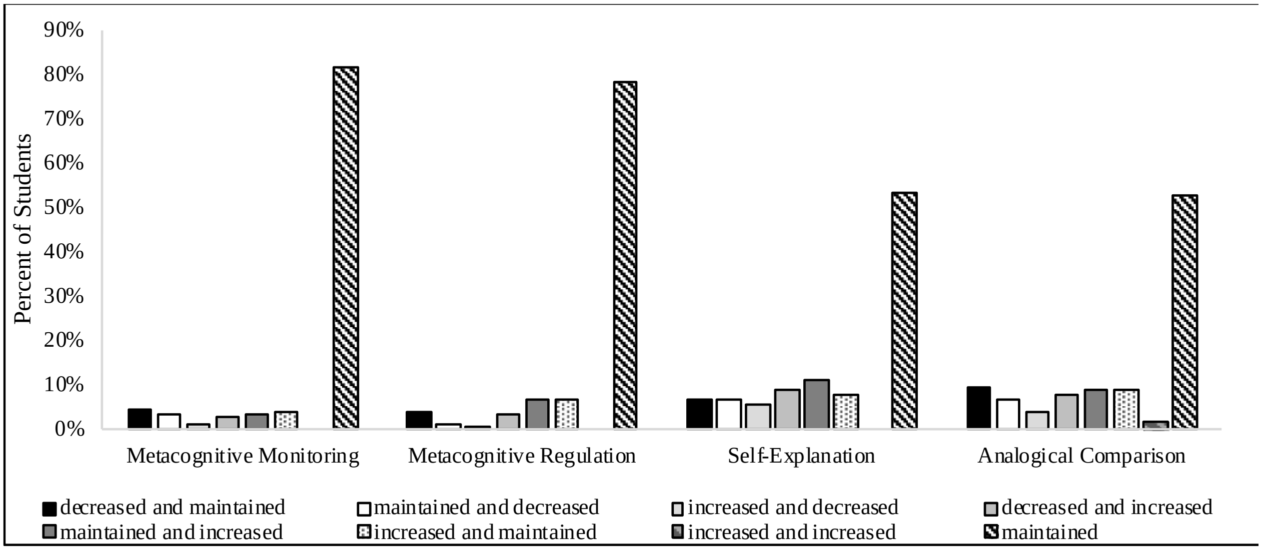


Figure 25. Percent of students who changed in their RCI scores for the Likert-scale strategies across each exam.

APPENDIX B

QUESTIONNAIRE VALIDITY AND STRUCTURE

To determine the validity and reliability for each of the Likert-scale questionnaires, I applied a two-step process. First, I examined the structure of the questionnaires by implementing an exploratory factor analysis (EFA) to evaluate whether the items were loading as separate constructs. Then I applied a confirmatory factor analysis (CFA) to evaluate whether those factors held true on later measures. Internal reliability is also reported for each of the factors with Cronbach's alpha and when appropriate the Spearman-Brown coefficient. For all EFAs, I used the psych (Revelle, 2018) and GPArotation (Bernaards & Jennrich, 2005) packages in R. For all CFAs, I used the lavaan R package (Rosseel, 2012). For the current study, the course variable was ignored and all students were treated as one group.

B.1 EFAS

For the initial questionnaire, I applied an EFA to determine if the initial grit and self-efficacy were loading as separate factors. The data were screened for outliers (+/- than 3 *SD*s). The same results appeared if those outliers were included or excluded from the analysis. Therefore, I included the variables in this analysis. A parallel analysis revealed that there were two predominant factors. A minimal residual method (minres) with an oblimin rotation, revealed that one item (Grit: "Setbacks don't discourage me") had a small factor loading of .38 and was removed. See Table 24 for the four factors and their item loadings. The first factor represents self-efficacy. The second factor represents grit. Each factor had adequate internal reliability. The resulting grit and self-efficacy measures had a small positive correlation (r = 0.23, p <.001). Students reported moderate use of grit (M = 3.48, SD = 0.71) and self-efficacy (M = 4.57, SD = 0.60).

Table 24. *EFA factor loadings for self-efficacy and grit.*

Construct	Item Number and Item	Factor 1	Factor 2
Grit	Setbacks don't discourage me.	Item Removed	
	I often set a goal but later choose to pursue a different one. (Rev)		0.71
	I have difficulty maintaining my focus on projects that take more than a few months to complete. (Rev)		0.65
	I finish whatever I begin.		0.59
Self-Efficacy	I am confident I will do well on cognitive psychology tests.	0.68	
	I am confident I will do well on cognitive psychology projects and assignments.	0.83	
	I am confident I will be able to help my classmates with cognitive psychology assignments and projects.	0.74	
	If I read a newspaper article on cognitive psychology, I could understand it.	0.59	
	If I wanted to, I could be good at conducting cognitive psychology research.	0.60	
	SS loadings	2.40	1.29
	% of Variance	0.30	0.16
	Cumulative %	0.30	0.46
	Internal Consistency	0.80	0.72

I also applied this same EFA process to the questionnaire that took place immediately before the first exam because that questionnaire contained a different variation of self-efficacy with only three items. It also included three new constructs examining metacognition, analogical comparison, and self-explanation. A parallel analysis revealed that there were four predominant factors. A minimal residual method (minres) with an oblimin rotation, revealed that three items had a small factor loading < .4 and was removed. See Table 25 for the four factors and their item loadings. The first factor represents self-efficacy. The second factor represents analogical comparison. The third reflects metacognitive regulation, and the fourth reflects metacognitive monitoring. Each factor within the model had adequate internal reliability for each of the factors (Table 25). Interestingly, the metacognitive construct was divided into two factors – one which reflected students being aware of what they did and did not know (i.e., metacognitive monitoring) and another that reflected adjusting and controlling their study habits (i.e., metacognitive regulation). These distinctions are theoretically meaningful as prior work defines and operates each of these factors (e.g., Schraw & Dennison, 1994). Metacognitive monitoring is declarative knowledge about what one's own knowledge such that they are able to determine what they do and do not know. Metacognitive regulation involves the control over one's cognitions. Students reported a moderate use of all the factors and these factors were all positively related to each other (Table 26).

Table 25. *EFA factor loadings for self-efficacy, metacognition, comparison and self-explanation.*

Construct	Item Number and Item	Factor 1	2	3	4	5
Self-Efficacy	1. I am confident I will do well on cognitive psychology tests.	0.71				
	2. I am confident I will do well on cognitive psychology projects and assignments.	0.87				
	3. I am confident I will be able to help my classmates with cognitive psychology assignments and projects.	0.67				
Metacognitive Regulation	1. The first thing I did was think through a plan for what, when, and how to study.				0.69	
	2. I tried to anticipate difficulties I might have had when learning certain ideas or concepts.			Item Removed		
	3. I kept track of how well I understood each concept.			Item Removed		
	4. I kept track of my progress, and if necessary, I changed my study strategies.				0.67	
Metacognitive Personal Knowledge	5. I knew when I understood a concept well.					0.58
	6. It was difficult for me to determine when I knew a concept well. (rev)					0.88
Self-Explanation	1. When I study, I pause to explain to myself difficult concepts so that I am sure I understand them.			0.96		
	2. If I don't understand something, I stop to try to explain it to myself.			0.78		
	3. When I study a new concept or example, I write out an explanation of it.			Item Removed		
Analogical Comparison	1. When I study, I compare and contrast different examples to one another.		0.93			
	2. To better understand one concept, I compare it to another one.		0.70			
	3. When studying class material, I compare and contrast different ideas to one another.		0.61			
	SS loadings	1.73	1.73	1.58	1.14	0.98
	% of Variance	0.14	0.14	0.13	0.10	0.08
	Cumulative %	0.14	0.29	0.42	0.51	0.60
	Internal Consistency	0.81	0.82	0.87 (0.87)	0.65 (0.65)	0.71 (0.73)

Note. In parentheses the internal consistency represents the Spearman-Brown coefficient which is a less biased measure for assessing internal consistency for 2-item assessments (Eisinga, Grotenhuis, & Pelzer, 2012).

Table 26. *Factor correlations.*

Factor	M	SD	1	2	3	4	5
1. Self-Efficacy	4.33	0.65	-				
2. Metacognitive Regulation	4.12	1.00	0.38	-			
3. Metacognitive Monitoring	4.41	0.88	0.42	0.25	-		
4. Self-Explanation	4.75	0.84	0.37	0.40	0.27	-	
5. Analogical Comparison	4.28	0.87	0.34	0.31	0.24	0.49	-

Note. For all correlations, $p < .001$

B.2 CFAS

Next, I applied a CFA to the questionnaire that took place before the second exam to confirm whether self-efficacy, metacognitive regulation, metacognitive monitoring, self-explanation, and analogical comparison were distinct factors. The resulting model had an adequate goodness-of-fit, CFI = .99 TLI = .98, RMSEA = .04 [90%CI: 0.01, 0.05] (Hu & Bentler, 1999). This finalized model also had adequate internal reliability for each of the factors (Table 27). For factor loadings and item descriptive statistics, see Table 28. Students reported a moderate use of all the factors and these factors were all positively related to each other.

Table 27. *CFA factor loadings for self-efficacy, metacognition, comparison and self-explanation.*

Latent Factor	Item Number	B	SE	Z	p-value	Beta	Internal Reliability
Self-Efficacy	1	0.60	0.03	17.47	<.001	0.81	0.87
Self-Efficacy	2	0.64	0.03	18.76	<.001	0.85	
Self-Efficacy	3	0.72	0.04	18.29	<.001	0.84	
Metacognitive Regulation	1	0.79	0.07	11.09	<.001	0.64	0.63 (0.64)
Metacognitive Regulation	4	0.77	0.06	12.32	<.001	0.73	
Metacognitive Monitoring	5	0.73	0.06	11.81	<.001	0.90	0.64 (0.65)
Metacognitive Monitoring	6	0.53	0.06	8.55	<.001	0.53	
Self-Explanation	1	0.76	0.04	18.78	<.001	0.89	0.86 (0.87)
Self-Explanation	2	0.77	0.04	18.05	<.001	0.86	
Analogical Comparison	1	0.79	0.04	17.67	<.001	0.84	0.87
Analogical Comparison	2	0.72	0.05	15.68	<.001	0.76	
Analogical Comparison	3	0.72	0.04	16.31	<.001	0.79	

Note. In parentheses the internal consistency represents the Spearman-Brown coefficient which is a less biased measure for assessing internal consistency for 2-item assessments (Eisinga et al., 2012).

Table 28. *Latent factor descriptive statistics and correlations.*

Factor	M	SD	1	2	3	4	5
1. Self-Efficacy	4.36	0.70	-				
2. Metacognitive Regulation	4.12	0.98	0.43	-			
3. Metacognitive Monitoring	4.39	0.78	0.39	0.18	-		
4. Self-Explanation	4.76	0.82	0.43	0.48	0.35	-	
5. Analogical Comparison	4.27	0.81	0.36	0.35	0.24	0.43	-

Note. For all correlations, $p < .001$

Then I applied a CFA to the questionnaire that took place before the third exam to confirm whether grit, self-efficacy, the two metacognitive factors, self-explanation, and analogical comparison were distinct factors. For this questionnaire, the self-efficacy measure mirrored that of the initial self-efficacy measure. The resulting model had an adequate goodness-of-fit, CFI = .96 TLI = .95, RMSEA = .05 [90%CI: 0.04, 0.06] (Hu & Bentler, 1999). See Table 29 for the factor loadings and Table 30 for the descriptive statistics and relations between the measures.

Table 29. *CFA factor loadings for grit, self-efficacy, metacognition, comparison and self-explanation.*

Latent Factor	Item Number	B	SE	*z*-value	*p*-value	Beta	Internal Reliability
Grit	2	0.57	0.05	10.38	<.001	0.62	0.68
Grit	3	0.57	0.06	9.46	<.001	0.56	
Grit	4	0.64	0.05	12.47	<.001	0.75	
Self-Efficacy	1	0.69	0.04	16.82	<.001	0.79	0.85
Self-Efficacy	2	0.66	0.04	17.01	<.001	0.80	
Self-Efficacy	3	0.73	0.04	16.39	<.001	0.78	
Self-Efficacy	4	0.52	0.04	13.27	<.001	0.66	
Self-Efficacy	5	0.69	0.05	12.97	<.001	0.65	
Metacognitive Regulation	1	0.74	0.07	11.21	<.001	0.64	0.64 (0.64)
Metacognitive Regulation	4	0.73	0.06	12.65	<.001	0.74	
Metacognitive Monitoring	5	0.85	0.08	10.39	<.001	1.04	0.65 (0.66)
Metacognitive Monitoring	6	0.48	0.07	7.22	<.001	0.48	
Self-Explanation	1	0.73	0.04	17.62	<.001	0.84	0.84 (0.84)
Self-Explanation	2	0.73	0.04	18.17	<.001	0.87	
Analogical Comparison	1	0.69	0.04	16.42	<.001	0.79	0.84
Analogical Comparison	2	0.73	0.04	16.81	<.001	0.80	
Analogical Comparison	3	0.75	0.04	16.88	<.001	0.80	

Note. In parentheses the internal consistency represents the Spearman-Brown coefficient which is a less biased measure for assessing internal consistency for 2-item assessments (Eisinga et al., 2012).

Table 30. *Latent factor correlations.*

Factor	M	SD	1	2	3	4	5	6
1. Grit	3.51	0.73	-					
2. Self-Efficacy	4.52	0.72	0.26	-				
3. Metacognitive Regulation	4.36	0.92	0.33	0.38	-			
4. Metacognitive Monitoring	4.43	0.79	0.25	0.34	0.19	-		
5. Self-Explanation	4.87	0.80	0.22	0.45	0.45	0.31	-	
6. Analogical Comparison	4.37	0.79	0.16	0.39	0.40	0.13	0.53	-

Note. Except for the correlation between analogical comparison and metacognitive monitoring (p = .01) and analogical comparison and grit (p = .003), all correlations are p <.001.

APPENDIX C

MEDIATION MODELS

All regression coefficients and interferential statistics for each model presented in Chapter 3. Each of the tables (Tables 31-35) refer to a corresponding figure presented in Chapter 3 (Figures 14-18). For these models, the continuous variables were standardized. The dichotomous variables were coded as - 0.5 or 0.5 so that the model represents the baseline across the dichotomous variables. If the CI contains 0, then the coefficient is not significant.

C.1 SELF-EFFICACY AND CONSTRUCTIVE STRATEGY USE MEDIATING THE EFFECT OF GRIT ON EXAM PERFORMANCE

Table 31. *Regression coefficients and information for path model in Figure 14.*

		M1 (Self-Efficacy)						M2 (Strategy Use)						Y (Exam Performance)					
	Antecedent		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI
Exam 1	X (Grit)	a_1	0.29	0.06	< .001	[0.17,	0.41]	a_2	0.27	0.07	< .001	[0.14,	0.41]	c'	0.01	0.06	.87	[-0.11,	0.13]
	M_1 (Self-Efficacy)		---	---	---	---	---		---	---	---	---	---	b_1	0.14	0.06	.01	[0.03,	0.26]
	M_2 (Strategy Use)		---	---	---	---	---		---	---	---	---	---	b_2	0.15	0.07	.04	[0.01,	0.29]
	C_1 (Rep.)	f_{11}	-0.02	0.25	.94	[-0.51,	0.48]	f_{12}	-0.34	0.23	.14	[-0.80,	0.12]	g_1	---	---	---	---	---
	C_2 (Sex)	f_{21}	-0.06	0.14	.66	[-0.33,	0.21]	f_{22}	0.20	0.14	.13	[-0.06,	0.47]	g_2	-0.13	0.19	.50	[-0.50,	0.25]
	C_3 (Age)	f_{31}	-0.02	0.06	.77	[-0.13,	0.10]	f_{32}	-0.05	0.08	.51	[-0.21,	0.10]	g_3	-0.09	0.12	.47	[-0.33,	0.15]
	C_4 (HS GPA)	f_{41}	-0.01	0.06	.81	[-0.13,	0.10]	f_{42}	-0.03	0.07	.65	[-0.17,	0.10]	g_4	0.02	0.08	.81	[-0.13,	0.17]
	C_5 (Class)	f_{51}	-0.04	0.11	.70	[-0.27,	0.18]	f_{52}	0.02	0.11	.84	[-0.19,	0.23]	g^5	0.33	0.06	< .001	[0.23,	0.44]
	Constant	i_{M1}	0.01	0.12	.96	[-0.24,	0.25]	i_{M2}	-0.19	0.12	.11	[-0.43,	0.05]	i_Y	0.04	0.10	.69	[-0.16,	0.25]
		$R^2 = 0.09$						$R^2 = 0.10$						$R^2 = 0.18$					
		$F(6,317) = 4.52, p < .001$						$F(6,317) = 4.41, p < .001$						$F(8,315) = 8.72, p < .001$					
Exam 2	X (Grit)	a_1	0.26	0.05	< .001	[0.16,	0.37]	a_2	0.27	0.06	< .001	[0.14,	0.39]	c'	0.05	0.06	.37	[-0.06,	0.16]
	M_1 (Self-Efficacy)		---	---	---	---	---		---	---	---	---	---	b_1	0.10	0.07	.17	[-0.04,	0.24]
	M_2 (Strategy Use)		---	---	---	---	---		---	---	---	---	---	b_2	0.10	0.07	.16	[-0.04,	0.24]
	C_1 (Rep.)	f_{11}	-0.39	0.23	.09	[-0.83,	0.06]	f_{12}	-0.31	0.22	.16	[-0.74,	0.12]	g_1	-0.05	0.15	.72	[-0.35,	0.24]
	C_2 (Sex)	f_{21}	-0.28	0.14	.04	[-0.55,	-0.01]	f_{22}	-0.02	0.13	.85	[-0.27,	0.22]	g_2	0.04	0.13	.75	[-0.21,	0.29]
	C_3 (Age)	f_{31}	-0.08	0.06	.19	[-0.20,	0.04]	f_{32}	-0.09	0.08	.29	[-0.25,	0.07]	g_3	0.00	0.09	.99	[-0.18,	0.18]
	C_4 (HS GPA)	f_{41}	0.02	0.06	.80	[-0.11,	0.14]	f_{42}	0.01	0.06	.83	[-0.10,	0.12]	g_4	0.21	0.06	< .001	[0.09,	0.32]
	C_5 (Class)	f_{51}	-0.19	0.11	.08	[-0.41,	0.03]	f_{52}	-0.05	0.11	.68	[-0.26,	0.17]	g^5	0.17	0.11	.12	[-0.05,	0.39]
	Constant	i_{M1}	-0.10	0.11	.40	[-0.32,	0.13]	i_{M2}	-0.12	0.11	.25	[-0.34,	0.09]	i_Y	-0.03	0.08	.67	[-0.18,	0.12]
		$R^2 = 0.11$						$R^2 = 0.09$						$R^2 = 0.10$					
		$F(6,317) = 5.73, p < .001$						$F(6,317) = 3.72, p = .001$						$F(8,315) = 4.03, p < .001$					

	Antecedent		M1 (Self-Efficacy)						M2 (Strategy Use)						Y (Exam Performance)				
			B	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI
Exam 3	X (Grit)	a_1	0.32	0.06	< .001	[0.2,	0.43]	a_2	0.27	0.06	< .001	[0.14,	0.40]	c'	-0.001	0.06	.98	[-0.12,	0.12]
	M_1 (Self-Efficacy)		---	---	---	---	---		---	---	---	---	---	b_1	0.14	0.06	.02	[0.02,	0.26]
	M_2 (Strategy Use)		---	---	---	---	---		---	---	---	---	---	b_2	0.13	0.06	.04	[0.01,	0.26]
	C_1 (Rep.)	f_{11}	-0.05	0.19	.78	[-0.43,	0.32]	f_{12}	0.02	0.24	.94	[-0.46,	0.49]	g_1	-0.13	0.18	.48	[-0.48,	0.23]
	C_2 (Sex)	f_{21}	-0.25	0.12	.04	[-0.48,	-0.02]	f_{22}	0.07	0.13	.61	[-0.19,	0.32]	g_2	-0.01	0.13	.97	[-0.25,	0.24]
	C_3 (Age)	f_{31}	0.04	0.06	.49	[-0.08,	0.16]	f_{32}	-0.03	0.10	.77	[-0.22,	0.17]	g_3	0.03	0.05	.51	[-0.06,	0.13]
	C_4 (HS GPA)	f_{41}	0.06	0.06	.34	[-0.06,	0.18]	f_{42}	-0.04	0.06	.51	[-0.15,	0.08]	g_4	0.25	0.06	< .001	[0.14,	0.36]
	C_5 (Class)	f_{51}	-0.02	0.11	.87	[-0.23,	0.20]	f_{52}	-0.08	0.11	.47	[-0.29,	0.13]	g^5	0.28	0.11	.008	[0.08,	0.49]
	Constant	i_{M1}	0.04	0.09	.70	[-0.15,	0.22]	i_{M2}	-0.01	0.12	.94	[-0.25,	0.23]	i_Y	-0.05	0.09	.58	[-0.23,	0.13]
			$R^2 = 0.12$						$R^2 = 0.07$						$R^2 = 0.14$				
			$F(6,317) = 6.76, p < .001$						$F(6,317) = 3.28, p = .004$						$F(8,315) = 8.15, p < .001$				

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

C.2 THE EFFECT OF ONE SRL CYCLE ON SUBSEQUENT SELF-EFFICACY

Table 32. *Regression coefficients and information for path model in Figure 15.*

Regression Model	Antecedent		*B*	*SE*	*p*	LLCI	ULCI
Regression 1 M_1 (Exam 1 Self-Efficacy)	X (Grit)	a_1	0.29	0.06	< .001	[0.17,	0.41]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{11}	-0.02	0.25	.94	[-0.51,	0.48]
	C_2 (Sex)	f_{21}	-0.06	0.14	.66	[-0.33,	0.21]
	C_3 (Age)	f_{31}	-0.02	0.06	.77	[-0.13,	0.10]
	C_4 (HS GPA)	f_{41}	-0.01	0.06	.81	[-0.13,	0.10]
	C_5 (Class)	f_{51}	-0.04	0.11	.70	[-0.27,	0.18]
	Constant	i_{M1}	0.01	0.12	.96	[-0.24,	0.25]
					$R^2 = 0.09$		
					$F(6,317) = 4.52$, $p < .001$		
Regression 2 M_2 (Exam 1 Strategy Use)	X (Grit)	a_2	0.27	0.07	< .001	[0.14,	0.41]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{12}	-0.34	0.23	.14	[-0.80,	0.12]
	C_2 (Sex)	f_{22}	0.20	0.14	.13	[-0.06,	0.47]
	C_3 (Age)	f_{32}	-0.05	0.08	.51	[-0.21,	0.10]
	C_4 (HS GPA)	f_{42}	-0.03	0.07	.65	[-0.17,	0.10]
	C_5 (Class)	f_{52}	0.02	0.11	.84	[-0.19,	0.23]
	Constant	i_{M2}	-0.19	0.12	.11	[-0.43,	0.05]
					$R^2 = 0.10$		
					$F(6,317) = 4.41$, $p < .001$		
Regression 3 M_3 (Exam 1 Performance)	X (Grit)	d_1	0.01	0.06	.87	[-0.11,	0.13]
	M_1 (Self-Efficacy)	d_2	0.14	0.06	.01	[0.03,	0.26]
	M_2 (Strategy Use)	d_3	0.15	0.07	.04	[0.01,	0.29]
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	g_1	-0.13	0.19	.50	[-0.50,	0.25]
	C_2 (Sex)	g_2	-0.09	0.12	.47	[-0.33,	0.15]
	C_3 (Age)	g_3	0.02	0.08	.81	[-0.13,	0.17]
	C_4 (HS GPA)	g_4	0.33	0.06	< .001	[0.23,	0.44]
	C_5 (Class)	g_5	0.04	0.10	.69	[-0.16,	0.25]
	Constant	i_{M3}	-0.03	0.10	.75	[-0.23,	0.16]
					$R^2 = 0.18$		
					$F(8,315) = 8.72$, $p < .001$		

Regression Model	Antecedent		B	SE	p	LLCI	ULCI
Regression 4 Y (Exam 2 Self-Efficacy)	X (Grit)	c'	0.06	0.04	.14	[-0.02,	0.14]
	M_1 (Self-Efficacy)	b_1	0.50	0.05	< .001	[0.40,	0.61]
	M_2 (Strategy Use)	b_2	0.16	0.06	.007	[0.04,	0.27]
	M_3 (Exam Performance)	b_3	0.13	0.05	.01	[0.03,	0.24]
	C_1 (Rep.)	g_1	-0.30	0.18	.09	[-0.65,	0.05]
	C_2 (Sex)	g_2	-0.27	0.10	.009	[-0.48,	-0.07]
	C_3 (Age)	g_3	-0.07	0.05	.16	[-0.16,	0.03]
	C_4 (HS GPA)	g_4	-0.02	0.05	.78	[-0.12,	0.09]
	C_5 (Class)	g_5	-0.18	0.08	.04	[-0.34,	-0.01]
	Constant	i_Y	-0.06	0.09	.51	[-0.24,	0.12]
					$R^2 = 0.48$		
					$F(9,314) = 32.29, p < .001$		

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

Table 33. *Regression coefficients and information for path model in Figure 15.*

Regression Model	Antecedent		B	SE	p	LLCI	ULCI
Regression 1 M_1 (Exam 2 Self-Efficacy)	X (Grit)	a_1	0.26	0.05	< .001	[0.16,	0.37]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{11}	-0.39	0.23	.09	[-0.83,	0.06]
	C_2 (Sex)	f_{21}	-0.28	0.14	.04	[-0.55,	-0.01]
	C_3 (Age)	f_{31}	-0.08	0.06	.19	[-0.20,	0.04]
	C_4 (HS GPA)	f_{41}	0.02	0.06	.80	[-0.11,	0.14]
	C_5 (Class)	f_{51}	-0.19	0.11	.08	[-0.41,	0.03]
	Constant	i_{M1}	-0.10	0.11	.40	[-0.32,	0.13]
					$R^2 = 0.11$		
					$F(6,317) = 5.73, p < .001$		
Regression 2 M_2 (Exam 2 Strategy Use)	X (Grit)	a_2	0.27	0.06	< .001	[0.14,	0.39]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{12}	-0.31	0.22	.16	[-0.74,	0.12]
	C_2 (Sex)	f_{22}	-0.02	0.13	.85	[-0.27,	0.22]
	C_3 (Age)	f_{32}	-0.09	0.08	.29	[-0.25,	0.07]
	C_4 (HS GPA)	f_{42}	0.01	0.06	.83	[-0.10,	0.12]
	C_5 (Class)	f_{52}	-0.05	0.11	.68	[-0.26,	0.17]
	Constant	i_{M2}	-0.12	0.11	.25	[-0.34,	0.09]
					$R^2 = 0.09$		
					$F(6,317) = 3.72, p = 0.001$		
Regression 3 M_3 (Exam 2 Performance)	X (Grit)	d_1	0.05	0.06	.37	[-0.06,	0.16]
	M_1 (Self-Efficacy)	d_2	0.10	0.07	.17	[-0.04,	0.24]
	M_2 (Strategy Use)	d_3	0.10	0.07	.16	[-0.04,	0.24]
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	g_1	-0.05	0.15	.72	[-0.35,	0.24]
	C_2 (Sex)	g_2	0.04	0.13	.75	[-0.21,	0.29]
	C_3 (Age)	g_3	0.00	0.09	.99	[-0.18,	0.18]
	C_4 (HS GPA)	g_4	0.21	0.06	< .001	[0.09,	0.32]
	C_5 (Class)	g_5	0.17	0.11	.12	[-0.05,	0.39]
	Constant	i_{M3}	-0.03	0.08	.67	[-0.18,	0.12]
					$R^2 = 0.10$		
					$F(8,315) = 4.03, p < .001$		

Regression Model	Antecedent		*B*	*SE*	*p*	LLCI	ULCI
Regression 4 Y (Exam 3 Self-Efficacy)	X (Grit)	*c'*	0.18	0.05	< .001	[0.08,	0.29]
	M_1 (Self-Efficacy)	b_1	0.24	0.06	< .001	[0.12,	0.36]
	M_2 (Strategy Use)	b_2	0.16	0.06	.01	[0.03,	0.28]
	M_3 (Exam Performance)	b_3	0.27	0.05	< .001	[0.17,	0.37]
	C_1 (Rep.)	g_1	0.12	0.16	.45	[-0.20,	0.44]
	C_2 (Sex)	g_2	-0.18	0.11	.10	[-0.39,	0.03]
	C_3 (Age)	g_3	0.08	0.05	.14	[-0.03,	0.19]
	C_4 (HS GPA)	g_4	0.00	0.05	.94	[-0.11,	0.10]
	C_5 (Class)	g_5	0.00	0.10	.96	[-0.20,	0.19]
	Constant	i_Y	0.09	0.08	.25	[-0.06,	0.25]
					$R^2 = 0.33$		
					$F(9,314) = 22.02, p < .001$		

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

C.3 THE EFFECT OF ONE SRL CYCLE ON SUBSEQUENT CONSTRUCTIVE STRATEGY USE

Table 34. *Regression coefficients and information for path model in Figure 17.*

Regression Model	Antecedent		*B*	*SE*	*p*	LLCI	ULCI
Regression 1 M_1 (Exam 1 Self-Efficacy)	X (Grit)	a_1	0.29	0.06	< .001	[0.17,	0.40]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{11}	-0.02	0.25	.94	[-0.51,	0.48]
	C_2 (Sex)	f_{21}	-0.06	0.14	.66	[-0.33,	0.21]
	C_3 (Age)	f_{31}	-0.02	0.06	.77	[-0.13,	0.10]
	C_4 (HS GPA)	f_{41}	-0.01	0.06	.81	[-0.13,	0.10]
	C_5 (Class)	f_{51}	-0.04	0.11	.70	[-0.27,	0.18]
	Constant	i_{M1}	0.01	0.12	.96	[-0.24,	0.25]
					$R^2 = 0.09$		
					$F(6,317) = 4.52, p < .001$		
Regression 2 M_2 (Exam 1 Strategy Use)	X (Grit)	a_2	0.27	0.07	< .001	[0.14,	0.41]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{12}	-0.34	0.23	.14	[-0.80,	0.12]
	C_2 (Sex)	f_{22}	0.20	0.14	.13	[-0.06,	0.47]
	C_3 (Age)	f_{32}	-0.05	0.08	.51	[-0.21,	0.10]
	C_4 (HS GPA)	f_{42}	-0.03	0.07	.65	[-0.17,	0.10]
	C_5 (Class)	f_{52}	0.02	0.11	.84	[-0.19,	0.23]
	Constant	i_{M2}	-0.19	0.12	.11	[-0.43,	0.05]
					$R^2 = 0.10$		
					$F(6,317) = 4.41, p < .001$		

Regression Model	Antecedent		B	SE	p	LLCI	ULCI
Regression 3 M_3 (Exam 1 Performance)	X (Grit)	d_1	0.01	0.06	.87	[-0.11,	0.13]
	M_1 (Self-Efficacy)	d_2	0.14	0.06	.01	[0.03,	0.26]
	M_2 (Strategy Use)	d_3	0.15	0.07	.04	[0.01,	0.29]
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	g_1	-0.13	0.19	0.50	[-0.50,	0.25]
	C_2 (Sex)	g_2	-0.09	0.12	0.47	[-0.33,	0.15]
	C_3 (Age)	g_3	0.02	0.08	0.81	[-0.13,	0.17]
	C_4 (HS GPA)	g_4	0.33	0.06	< .001	[0.23,	0.44]
	C_5 (Class)	g_5	0.04	0.10	0.69	[-0.16,	0.25]
	Constant	i_{M3}	-0.03	0.10	0.75	[-0.23,	0.16]
					$R^2 = 0.18$		
					$F(8,315) = 8.72$, $p < .001$		
Regression 4 Y (Exam 2 Strategy Use)	X (Grit)	c'	0.06	0.05	.21	[-0.04,	0.16]
	M_1 (Self-Efficacy)	b_1	0.17	0.05	< .001	[0.08,	0.26]
	M_2 (Strategy Use)	b_2	0.54	0.06	< .001	[0.42,	0.66]
	M_3 (Exam Performance)	b_3	0.04	0.05	.45	[-0.06,	0.14]
	C_1 (Rep.)	g_1	-0.11	0.19	.56	[-0.49,	0.27]
	C_2 (Sex)	g_2	-0.12	0.09	.19	[-0.30,	0.06]
	C_3 (Age)	g_3	-0.06	0.05	.28	[-0.16,	0.05]
	C_4 (HS GPA)	g_4	0.02	0.04	.68	[-0.07,	0.10]
	C_5 (Class)	g_5	-0.05	0.09	.55	[-0.22,	0.12]
	Constant	i_Y	-0.02	0.09	.85	[-0.20,	0.17]
					$R^2 = 0.48$		
					$F(9,314) = 36.59$, $p < .001$		

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

Table 35. *Regression coefficients and information for path model in Figure 18.*

Regression Model	Antecedent		*B*	*SE*	*p*	LLCI	ULCI
Regression 1 M_1 (Exam 2 Self-Efficacy)	X (Grit)	a_1	0.26	0.05	< .001	[0.16,	0.37]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{11}	-0.39	0.23	.09	[-0.83,	0.06]
	C_2 (Sex)	f_{21}	-0.28	0.14	.04	[-0.55,	-0.01]
	C_3 (Age)	f_{31}	-0.08	0.06	.19	[-0.20,	0.04]
	C_4 (HS GPA)	f_{41}	0.02	0.06	.80	[-0.11,	0.14]
	C_5 (Class)	f_{51}	-0.19	0.11	.08	[-0.41,	0.03]
	Constant	i_{M1}	-0.10	0.11	.40	[-0.32,	0.13]
					$R^2 = 0.11$		
					$F(6,317) = 5.73, p <.001$		
Regression 2 M_2 (Exam 2 Strategy Use)	X (Grit)	a_2	0.27	0.06	< .001	[0.14,	0.39]
	M_1 (Self-Efficacy)		---	---	---	---	---
	M_2 (Strategy Use)		---	---	---	---	---
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	f_{12}	-0.31	0.22	.16	[-0.74,	0.12]
	C_2 (Sex)	f_{22}	-0.02	0.13	.85	[-0.27,	0.22]
	C_3 (Age)	f_{32}	-0.09	0.08	.29	[-0.25,	0.07]
	C_4 (HS GPA)	f_{42}	0.01	0.06	.83	[-0.10,	0.12]
	C_5 (Class)	f_{52}	-0.05	0.11	.68	[-0.26,	0.17]
	Constant	i_{M2}	-0.12	0.11	.25	[-0.34,	0.09]
					$R^2 = 0.09$		
					$F(6,317) = 3.72, p = .001$		
Regression 3 M_3 (Exam 2 Performance)	X (Grit)	d_1	0.05	0.06	.37	[-0.06,	0.16]
	M_1 (Self-Efficacy)	d_2	0.10	0.07	.17	[-0.04,	0.24]
	M_2 (Strategy Use)	d_3	0.10	0.07	.16	[-0.04,	0.24]
	M_3 (Exam Performance)		---	---	---	---	---
	C_1 (Rep.)	g_1	-0.05	0.15	.72	[-0.35,	0.24]
	C_2 (Sex)	g_2	0.04	0.13	.75	[-0.21,	0.29]
	C_3 (Age)	g_3	0.00	0.09	.99	[-0.18,	0.18]
	C_4 (HS GPA)	g_4	0.21	0.06	< .001	[0.09,	0.32]
	C_5 (Class)	g_5	0.17	0.11	.12	[-0.05,	0.39]
	Constant	i_{M3}	-0.03	0.08	.67	[-0.18,	0.12]
					$R^2 = 0.10$		
					$F(8,315) = 4.03, p < .001$		
Regression 4 Y (Exam 3 Strategy Use)	X (Grit)	c'	0.07	0.05	.16	[-0.03,	0.16]
	M_1 (Self-Efficacy)	b_1	0.21	0.06	< .001	[0.10,	0.32]
	M_2 (Strategy Use)	b_2	0.51	0.06	< .001	[0.39,	0.63]
	M_3 (Exam Performance)	b_3	0.10	0.04	.02	[0.02,	0.19]
	C_1 (Rep.)	g_1	0.27	0.18	.14	[-0.09,	0.63]
	C_2 (Sex)	g_2	0.14	0.10	.18	[-0.06,	0.34]
	C_3 (Age)	g_3	0.04	0.07	.62	[-0.11,	0.18]
	C_4 (HS GPA)	g_4	-0.07	0.04	.12	[-0.16,	0.02]
	C_5 (Class)	g_5	-0.03	0.08	.72	[-0.19,	0.13]
	Constant	i_Y	0.08	0.09	.39	[-0.10,	0.26]
					$R^2 = 0.48$		
					$F(9,314) = 27.78, p < .001$		

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

APPENDIX D

MODERATED MEDIATION MODELS

All regression coefficients and interferential statistics for the models presented in Chapter 4. For these models (Figures 19-21; Tables 36-38), the continuous variables were standardized. Except for representation status, which was coded as 1 for underrepresented and 0 for represented, the other dichotomous variables were coded as - 0.5 or 0.5 so that the model represents the baseline across the other dichotomous variables. If the CI contains 0, then the coefficient is not significant.

Table 36. *Regression coefficients and information for path model in Figure 19.*

		M_1 (Self-Efficacy)						M_2 (Strategy Use)						Y (Exam Performance)				
Antecedent		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI
X (Grit)	a_{11}	0.32	0.06	< .001	[0.20,	0.44]	a_{12}	0.32	0.07	< .001	[0.19,	0.45]	c'	0.04	0.06	.53	[-0.08,	0.16]
W (Rep.)	a_{21}	-0.11	0.24	.63	[-0.58,	0.35]	a_{22}	-0.50	0.22	.02	[-0.93,	-0.07]	c_2'	-0.21	0.22	.34	[-0.66,	0.23]
X x W	a_{31}	-0.32	0.18	.08	[-0.69,	0.04]	a_{32}	-0.53	0.24	.03	[-1.00,	-0.05]	c_3'	-0.28	0.22	.21	[-0.71,	0.15]
M_1 (Self-Efficacy)		---	---	---	---	---		---	---	---	---	---	b_1	0.14	0.06	.02	[0.03,	0.26]
M_2 (Strategy Use)		---	---	---	---	---		---	---	---	---	---	b_2	0.13	0.07	.06	[0.00,	0.27]
C_1 (Sex)	f_{11}	-0.07	0.14	.59	[-0.34,	0.20]	f_{12}	0.18	0.13	.18	[-0.08,	0.45]	g_1	-0.21	0.22	.34	[-0.66,	0.23]
C_2 (Age)	f_{21}	-0.02	0.06	.77	[-0.13,	0.10]	f_{22}	-0.05	0.08	.51	[-0.22,	0.11]	g_2	-0.28	0.22	.21	[-0.71,	0.15]
C_3 (HS GPA)	f_{31}	-0.01	0.06	.86	[-0.12,	0.10]	f_{32}	-0.02	0.07	.72	[-0.16,	0.11]	g_3	-0.10	0.12	.43	[-0.34,	0.15]
C_4 (Class)	f_{41}	-0.02	0.11	.84	[-0.24,	0.20]	f_{42}	0.06	0.11	.58	[-0.15,	0.27]	g_4	0.02	0.08	.82	[-0.13,	0.17]
Constant	i_M	0.02	0.07	.79	[-0.12,	0.16]	i_M	-0.02	0.07	.82	[-0.15,	0.12]	i_Y	0.03	0.06	.57	[-0.09,	0.15]
		$R^2 = 0.09$						$R^2 = 0.12$						$R^2 = 0.19$				
		$F(7,316) = 4.15, p < .001$						$F(7,316) = 5.06, p < .001$						$F(9,314) = 7.85, p < .001$				

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

Table 37. *Regression coefficients and information for path model in Figure 20.*

Antecedent		M₁ (Self-Efficacy)						M₂ (Strategy Use)						Y (Exam Performance)				
		B	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI
X (Grit)	a_{11}	0.29	0.06	< .001	[0.18,	0.40]	a_{12}	0.28	0.07	< .001	[0.16,	0.41]	c'	0.03	0.06	.58	[-0.09,	0.15]
W (Rep.)	a_{21}	-0.48	0.23	.04	[-0.94,	-0.03]	a_{22}	-0.37	0.21	.08	[-0.80,	0.05]	c_2'	-0.0003	0.15	.998	[-0.29,	0.29]
X x W	a_{31}	-0.32	0.20	.11	[-0.70,	0.07]	a_{32}	-0.21	0.30	.47	[-0.80,	0.37]	c_3'	0.18	0.14	.20	[-0.09,	0.44]
M_1 (Self-Efficacy)		---	---	---	---	---		---	---	---	---	---	b_1	0.10	0.07	.16	[-0.04,	0.25]
M_2 (Strategy Use)		---	---	---	---	---		---	---	---	---	---	b_2	0.10	0.07	.15	[-0.04,	0.25]
C_1 (Sex)	f_{11}	-0.29	0.14	.03	[-0.56,	-0.03]	f_{12}	-0.03	0.13	.79	[-0.28,	0.21]	g_1	0.05	0.13	.70	[-0.21,	0.3]
C_2 (Age)	f_{21}	-0.08	0.06	.18	[-0.20,	0.04]	f_{22}	-0.09	0.08	.29	[-0.25,	0.08]	g_2	-0.001	0.09	.995	[-0.18,	0.18]
C_3 (HS GPA)	f_{31}	0.02	0.06	.76	[-0.11,	0.14]	f_{32}	0.01	0.06	.79	[-0.09,	0.12]	g_3	0.21	0.06	< .001	[0.09,	0.32]
C_4 (Class)	f_{41}	-0.17	0.11	.13	[-0.39,	0.05]	f_{42}	-0.03	0.11	.78	[-0.25,	0.18]	g_4	0.16	0.11	.15	[-0.06,	0.38]
Constant	i_M	0.10	0.07	.15	[-0.04,	0.24]	i_M	0.03	0.06	.59	[-0.09,	0.15]	i_Y	-0.01	0.07	.92	[-0.14,	0.12]
		$R^2 = 0.12$						$R^2 = 0.09$						$R^2 = 0.10$				
		$F(7,316) = 5.52$, $p < .001$						$F(7,316) = 3.77$, $p <.001$						$F(9,314) = 3.86$, $p <.001$				

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

Table 38. *Regression coefficients and information for path model in Figure 21.*

Antecedent		M₁ (Self-Efficacy)						M₂ (Strategy Use)						Y (Exam Performance)				
		B	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI		*B*	*SE*	*p*	LLCI	ULCI
X (Grit)	a_{11}	0.30	0.06	< .001	[0.19,	0.42]	a_{12}	0.30	0.07	< .001	[0.17,	0.43]	c'	0.01	0.06	.88	[-0.11,	0.13]
W (Rep.)	a_{21}	-0.02	0.20	.94	[-0.41,	0.38]	a_{22}	-0.10	0.27	.72	[-0.62,	0.43]	c_2'	-0.16	0.19	.41	[-0.54,	0.22]
X x W	a_{31}	0.13	0.18	.47	[-0.23,	0.49]	a_{32}	-0.39	0.24	.10	[-0.85,	0.08]	c_3'	-0.12	0.18	.51	[-0.47,	0.23]
M_1 (Self-Efficacy)		---	---	---	---	---		---	---	---	---	---	b_1	0.15	0.06	.02	[0.02,	0.27]
M_2 (Strategy Use)		---	---	---	---	---		---	---	---	---	---	b_2	0.13	0.06	.05	[0.002,	0.25]
C_1 (Sex)	f_{11}	-0.24	0.12	.04	[-0.47,	-0.01]	f_{12}	0.05	0.13	.70	[-0.21,	0.31]	g_1	-0.01	0.13	.94	[-0.26,	0.24]
C_2 (Age)	f_{21}	0.04	0.06	.49	[-0.08,	0.16]	f_{22}	-0.03	0.10	.77	[-0.23,	0.17]	g_2	0.03	0.05	.52	[-0.06,	0.13]
C_3 (HS GPA)	f_{31}	0.06	0.06	.36	[-0.06,	0.18]	f_{32}	-0.03	0.06	.56	[-0.15,	0.08]	g_3	0.25	0.06	< .001	[0.14,	0.36]
C_4 (Class)	f_{41}	-0.03	0.11	.81	[-0.24,	0.19]	f_{42}	-0.05	0.11	.63	[-0.26,	0.16]	g_4	0.29	0.10	.006	[0.08,	0.50]
Constant	i_M	0.06	0.06	.31	[-0.06,	0.18]	i_M	-0.01	0.06	.81	[-0.14,	0.11]	i_Y	0.01	0.07	.84	[-0.11,	0.14]
		$R^2 = 0.12$						$R^2 = 0.08$						$R^2 = 0.15$				
		$F(7,316) = 5.81$, $p <.001$						$F(7,316) = 3.24$, $p =0.003$						$F(9,314) = 7.18$, $p < .001$				

Note. *B* = coefficient, LLCI = lower bound CI for the coefficient, ULCI = upper bound CI for the coefficient, Rep. = Representation, HS GPA = high school grade point average.

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