Promoting the Self-Regulated Use of Elaboration and Retrieval Practice

in an Undergraduate Biology Course

Abstract

Retrieval practice (i.e., recalling information from memory) and *elaboration* (i.e., generating meaningful explanations and examples) promote learning, but students underutilize these strategies when studying. We developed a strategy-training intervention addressing prominent barriers to students' strategy use: lack of knowledge, lack of motivation, and poor management of study time. Undergraduates in an Introductory Biology course were randomly assigned to receive the strategy-training intervention or to a healthy life habits control group. No significant differences were found between the two groups on measures of learning behavior or achievement collected across the semester, emphasizing the challenge of changing students' learning habits. Future research should investigate strategy training with lower-performing students integrated into a course.

1. Objectives

Although over a quarter of U.S. college students select a science major, more than half of these students switch to another field or fail to earn any credentials[1]. Most students who leave science programs do so after earning low or non-passing grades in challenging "gateway" courses, such as introductory biology[2]. One contributing factor to students' science departure is their lack of preparedness for the demands of rigorous science courses. Many students enter college with insufficient awareness of effective learning strategies and struggle to adopt strategies that promote lasting learning[3]. Thus, there is a clear need for training programs that can help undergraduates develop and maintain learning strategies that are effective across a range of science content[4].

McDaniel and Einstein[5] proposed a theoretical framework for promoting the use of effective learning strategies through training. Informed by models of self-regulated learning[6], they argue that the four critical components for strategy training are (1) *knowledge* about the strategies and how to use them, (2) *belief* that the strategies are effective, (3) *commitment* to implementing the strategies, and (4) a formulated *plan for implementation* of the strategies during self-regulated learning. We experimentally evaluated this framework in an undergraduate biology course. Specifically, we asked: Does a training intervention informed by the *Knowledge, Belief, Commitment,* and *Planning* framework lead to greater use of effective learning strategies compared to a control group?

2. Theoretical Framework

Cognitive and educational psychologists have identified learning strategies that help students gain, maintain, and apply knowledge. Two such strategies are *retrieval practice* and *elaboration*[7]. Retrieval practice involves bringing information to mind from long-term memory at some point after initial study[8]. Students can incorporate retrieval practice into their studying in a variety of ways, such as by taking practice tests, using flashcards, or explaining a concept to someone else. Elaboration refers to a class of strategies that involve actively integrating material and making connections, such as explaining how to-be-learned information is related to already known information, comparing and contrasting course concepts, or explaining steps taken during problem-solving[9]. We focused on these strategies for three primary reasons: (1) they are effective for learning across a broad range of outcomes (e.g., memory, comprehension, application) and have demonstrated effectiveness in undergraduate science courses[10,11], (2) they can be easily implemented by students, and most importantly, (3) students tend to underutilize them[12]. To motivate our approach, we discuss four barriers to implementing these strategies and our approach to addressing them through a strategy-training intervention (Table 1).

Barrier #1: Knowledge

Models of self-regulated learning emphasize knowledge of strategies as critical for adopting them[13]. However, students often lack accurate knowledge about the effectiveness of various strategies – for example, students tend to rate rereading and highlighting as more effective than retrieval practice.[14] One likely explanation for why students lack knowledge about effective strategies is that they are never taught about them.[15] Accordingly, a multitude of research has investigated the effectiveness of instruction about strategies on student knowledge, beliefs, strategy use, and achievement.[16,17] Results from these studies suggest that strategy instruction should include elaborated information about *why* a strategy is effective[18] and examples of when and how to apply such strategies (i.e., *conditional knowledge*[19]). In the strategy-training intervention, knowledge about effective strategies was communicated via dynamic instruction that emphasized evidence about the benefits of retrieval practice and elaboration, provided examples of how to use the strategies effectively for biology content, and addressed misconceptions about less effective strategies.

Barrier #2: Beliefs

For learners to engage in the sustained use of a learning strategy, they must be convinced that it consistently improves their own learning.[20] Learners often believe that strategies that enhance most

people's learning may not enhance their own.[21] Thus, simply having knowledge that a strategy is effective is not sufficient for adopting it – learners must also believe the strategy works *for them*. One effective way to convince students a strategy is effective for them is by experiencing the effects of the strategy on one's own memory performance.[22] The strategy-training intervention instilled belief about the effectiveness of each strategy via a demonstration. Specifically, students learned one set of target material via rereading and highlighting (i.e., relatively ineffective but commonly used strategies), and another set of material through elaboration and retrieval practice. One week later, students took a final test on both sets of material and received explicit feedback regarding their performance for each set of material. To ensure this demonstration was convincing, we controlled factors such as study time and material difficulty to isolate the learning strategy as the cause of differential memory performance.

Barrier #3: Commitment

An additional challenge for students is that they may feel incapable or unwilling to invest the effort required to change their learning habits[23]. For students to adopt effective strategies, finding methods to increase motivation to invest the required effort is critical.[24] To increase students' motivation and commitment, we developed a *utility-value intervention*. Utility-value interventions have the goal of "increase[ing] students' perceptions of the relevance of academics to their lives".[25] Specifically, students wrote a couple of paragraphs in which they reflected on how engaging in elaboration and/or retrieval practice would help them reach a specific academic goal (e.g., performing well on course exams).

Barrier #4: Planning

Finally, even if students commit to using effective strategies during learning, they may not make plans to use them[15], or they may lack the self-regulatory skills necessary to carry out such plans (e.g., avoiding distractions[26]). Students in the strategy-training intervention were encouraged to: (1) develop a "study plan" for how they would implement particular strategies each week (distributed across time for maximal benefits), and (2) link their study plan to specific situations (i.e., when and where) in which their plan will be implemented. This second feature is called an *implementation intention*, which takes the form "When situation *x* arises, I will perform response *y*".[27] Implementation intentions are effective because they help people overcome common challenges on the path to completing their plans (e.g., getting started or getting derailed).

3. Methods

Participants

Students were recruited from a 16-week Introductory Biology course at Texas Christian University to participate for a combination of extra credit and monetary compensation. Of the approximately 400 students enrolled in the course, 40 students completed all measures. An additional 14 students consented to participate but dropped the course.

Participating students were M_{age} = 18.43 years (*SE* = 0.13), 72.5% women, 25% men, and 2.5% nonbinary; 42.5% White, 22.5% Asian, 15.0% Black, 10.0% Hispanic/Latino, and 10.0% mixed race/ethnicity. Participants were primarily first-year students (67.5%) majoring in Biology (45.0%) or Biochemistry (22.5%), and 17.5% identified as first-generation college students.

Procedure

Table 2 provides an overview of the procedure and measures. Students were randomly assigned to either the strategy-training intervention group (*n* = 21) or to a control group (*n* = 19) that received a healthy habits intervention. During weeks 5-9, all students received the intervention appropriate to their group assignment. Both interventions were conducted in small groups in a classroom on campus. The training sessions took two hours to complete and were spaced across two sessions (approximately two weeks apart).

Participants in the strategy-training intervention group experienced the four components outlined in Table 1. Specifically, students participated in dynamic instruction on how and why they should implement effective learning strategies, experienced a demonstration of the consequences of using (vs. not using) such strategies, underwent a utility-value intervention (i.e., reflected on how using effective strategies would benefit them), and practiced making a study plan and implementation intention (i.e., thinking through when, where, and how they would use effective strategies for their biology course).

Meanwhile, participants in the healthy habits intervention group listened to a lecture about the importance of maintaining their health (e.g., emphasizing healthy eating and exercise, proper sleep hygiene, taking social breaks) for their academics,[28] reflected on their current life habits, and made a plan for incorporating healthy habits. We included an unrelated intervention as a control to help downplay the existence of two separate groups (given that students assigned to each group were in the same course).

At the end of the semester, all participants received access to materials from both training groups and were debriefed.

4. Data Sources and Evidence

Strategy Beliefs. Students reported their strategy beliefs prior to the administration of the intervention (pretest during week 5) and at the end of the semester (posttest during week 16). Students responded on a 1 – 10 scale (ranging from "very ineffective" to "very effective") to the question, "How effective are each of the following learning strategies for your Biology course?" The list of strategies is presented in Table 3.

Self-Regulated Learning Behavior. During weeks 6-15 of the semester, students completed five web-based surveys on their self-regulated learning behavior during the prior week. Specifically, students reported (1) how many minutes they spent studying on each of the preceding 7 days, and (2) whether they used particular learning strategies during that time (see Table 3 for strategy list).

Course Exam Performance. The course included four exams (during weeks 4, 8, 12, and 16) and a cumulative final at the end of the semester. Exams involved a combination of multiple-choice and short-answer questions primarily at the *understand* and *apply* levels of Bloom's taxonomy.[29] Intervention procedures were administered after students completed their first course exams, so exams 1 and 2 served as a baseline measure of course performance to provide a more sensitive test of strategy-training effects.

5A. Results

Strategy Beliefs. Students' strategy beliefs on the pretest and posttest are presented in Figure 1. Even before implementing the intervention (i.e., on the pretest), students tended to rate retrieval practice and elaboration-based strategies as effective. Multiple 2 (group: control, strategy training) x 2 (time: pretest, posttest) mixed ANOVAs on students' ratings of strategy effectiveness revealed no significant effects, suggesting that strategy beliefs did not change across the semester or differ between the two groups.

Self-Regulated Learning Behavior. Days spent studying and minutes reported studying across the semester are presented in Figures 2 and 3, respectively. Averaged across the five surveys, students reported studying an average of 4.78 days (SE = 0.40) for an average of 296.96 minutes (SE = 56.91) – about 5 hours – per week. Multiple 2 (group) x 5 (survey: 1, 2, 3, 4, 5) mixed ANOVAs revealed that these values did not significantly differ between the two groups, ps > .06. Figure 4 presents the proportion of students who reported using each strategy (averaged across the five surveys); no significant differences were found between the two groups in strategy use.

Course Exam Performance. Exam performance is presented in Figure 5. We conducted a 2 (group) x 5 (exam: 1, 2, 3, 4, final) mixed ANOVA on exam performance. Although exam performance tended to increase across the semester ($F(1, 38) = 68.09$, $p < .001$, $\eta_p^2 = 0.64$), the effect of group and the 2 x 2 interaction were not significant, ps > .25. Thus, the strategy-training intervention did not influence exam performance.

5B. Conclusions

To summarize, strategy beliefs, learning behavior, and exam performance did not significantly differ between students who received the strategy-training intervention and students who received a healthy habit intervention. One important limitation of our experiment is that only a small proportion of students in the course self-selected to participate. Participating students already had accurate strategy beliefs and performed well on course exams at the beginning of the semester, so they may not have benefitted from the intervention as much as other students – particularly lower-performing students[30] – in the course. Future research should continue to identify factors that hinder and facilitate strategy change for students.[30-32]

6. Significance

Although a multitude of research has established retrieval practice and elaboration as highly effective strategies, little research has focused on how to improve students' self-regulated use of such strategies in applied contexts. We addressed this gap by investigating the effects of a strategy-training intervention on multiple outcomes in a critical science course. Although we found no significant effects of the strategy training, outcomes provide a multifaceted depiction of students' strategy use across a semester, which can inform further iterations of strategy-training interventions.

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Table 1. Overview of the strategy-training intervention.

Component Addressed	Intervention Ingredient	Predicted Effects
Knowledge (Barrier #1)	*Instruction:* Dynamic discussion and activities that address when, why, and how to use effective learning strategies for biology material	Help students understand the strategies, evidence for their effectiveness, and how to apply them
Belief (Barrier #2)	*Demonstration:* Students experience the memorial consequences (with explicit feedback) for when they do and do not use effective strategies	Convince students the strategy works for them; increase self-efficacy over learning
Commitment (Barrier #3)	*Utility-value intervention:* Students think through the value of using effective strategies in their own studying	Help students appreciate the value of using effective strategies which can increase motivation to use them
Planning (Barrier #4)	*Implementation intention:* Students form study plan and think through when, where, and how they will incorporate effective strategies into their studying	Help students make and follow through on study plans

Table 2. Overview of experimental procedure and outcome measures.

	Week of Semester:	5-9	10	11	13	15	16	Final
		Training Sessions						
Outcome Measures:	Strategy Beliefs:	Pretest					Posttest	
	Learning Behavior:	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5		
	Course Achievement:	Exam 1 & 2		Exam 3		Exam 4		Final Exam

Table 3. Strategies listed on the measures of strategy beliefs and self-regulated learning behavior.

All 20 strategies were listed on the pretest and posttest measuring strategy beliefs. Students responded on a 1 – 10 scale (ranging from "very ineffective" to "very effective") to the question, "How effective are each of the following learning strategies for your Biology course?"

Strategies denoted with an asterisk (*) were included on the self-regulated learning measures. Students selected from a list which strategies they had used in the preceding 7 days.

	Strategy Label	Description
	Rereading*	Rereading course materials, such as the textbook, notes, or slides
	Copying*	Copying, rewriting, or re-organizing course materials, such as notes or sections of the textbook
	Rehearsing*	Rehearsing course materials over and over in order to memorize it
	Highlighting*	Highlighting or underlining course material, such as the textbook or notes
Elaboration	Generating*	Generating explanations for why a biology fact is true, how a biological process works, the steps taken during problem solving, and/or how the material could be applied in new contexts
Elaboration	Explaining*	Explaining to myself how course material relates to my existing knowledge or experience
Elaboration	Examples*	Creating my own examples to illustrate points made in the course material
Elaboration	Comparison*	Comparing or contrasting different course concepts to one another
Retrieval Practice	Testing	Testing myself on course material in any way, such as by taking practice tests, trying to recall or draw material from memory, doing practice problems, explaining course material to others, and/or using flashcards
Retrieval Practice	Covert Testing*	Testing myself by recalling information silently in my head
Retrieval Practice	Overt Testing*	Testing myself by saying information out loud or writing the information down
Retrieval Practice	Many Tests*	Testing myself multiple times on the same course material
Retrieval Practice	Testing Before*	Testing myself before I begin studying for biology to determine what I do or do not know
Retrieval Practice	Testing After*	Testing myself to find out what I know or do not know after studying for biology
	Schedule	Making a weekly study schedule for biology
	Tech Tools*	Using technological tools (such as an alarm clock or browser extension) to help me stick to a study schedule and/or limit distractions while studying for biology
	Spacing*	Studying some course material and then coming back to restudy the same material within the same study session and/or on another day
	Cramming	Studying in a single session before a biology exam (i.e., cramming)
	Spread Out	Spreading out my study sessions over multiple days or weeks before a biology exam
	Goals	Setting specific goals for learning in the course and monitoring my progress

Figure 1. Students' average rating of effectiveness on the pretest (top graph) and posttest (bottom graph) by group assignment. Error bars reflect standard error of the mean.

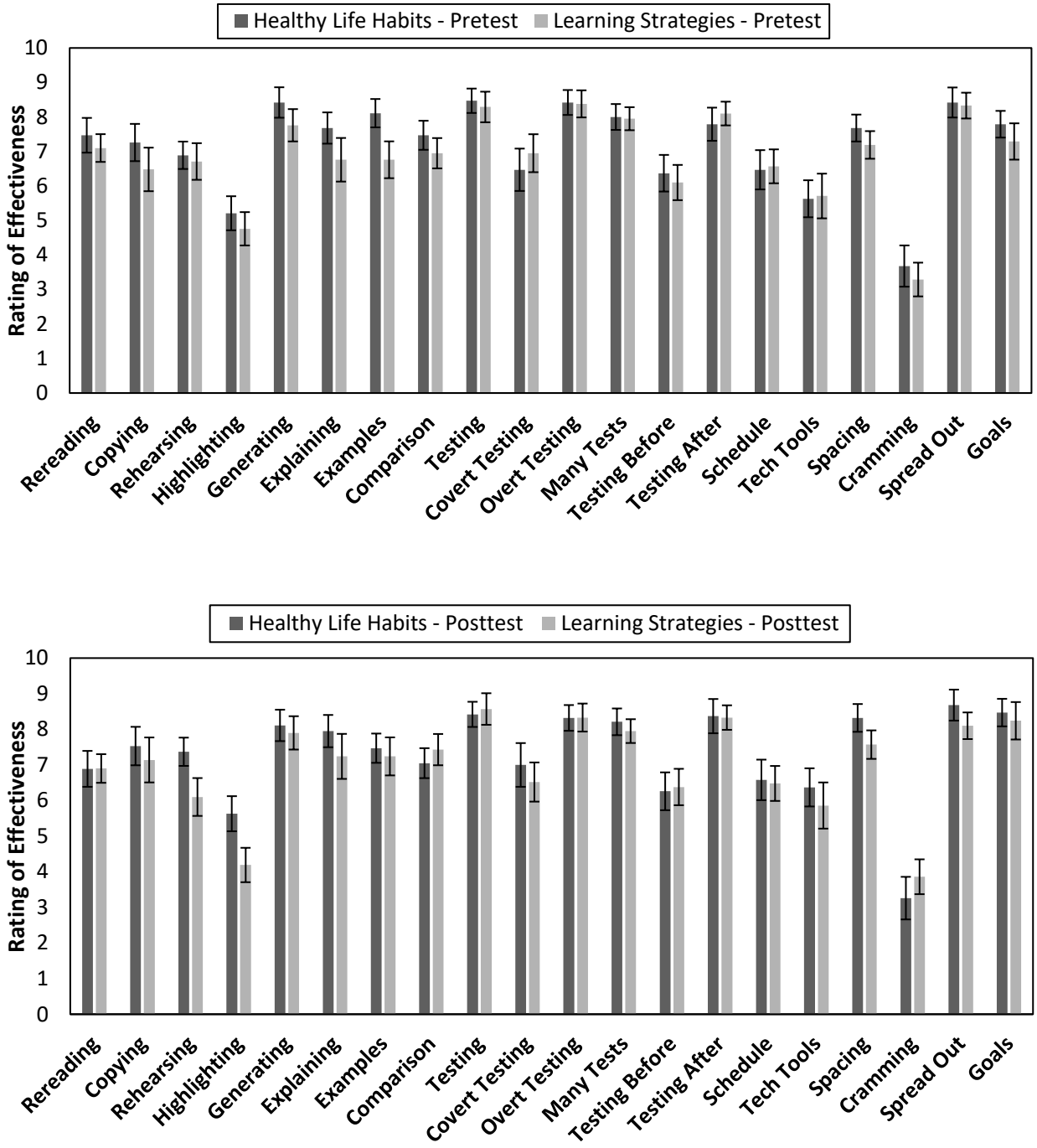

Figure 2. Average number of days students reported studying in the preceding 7 days on each survey by group assignment. Error bars reflect standard error of the mean.

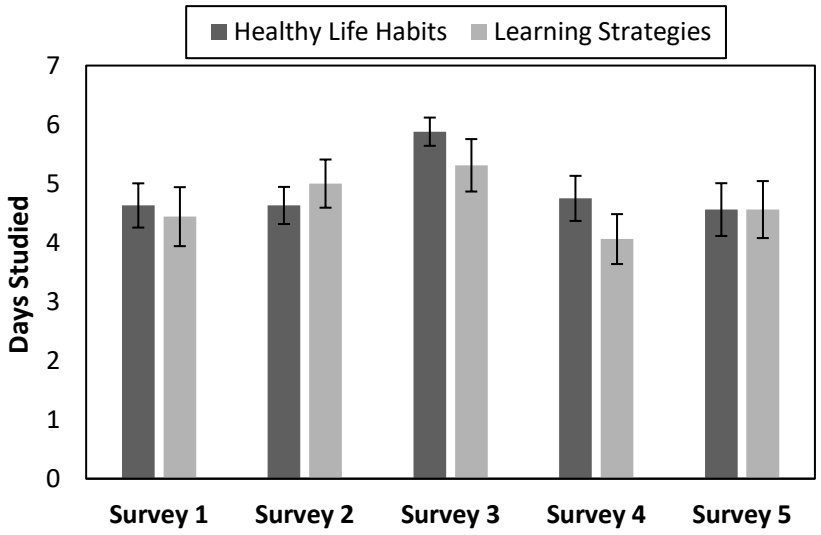

Figure 3. Average number of minutes spent studying in the preceding 7 days on each survey by group assignment. Error bars reflect standard error of the mean.

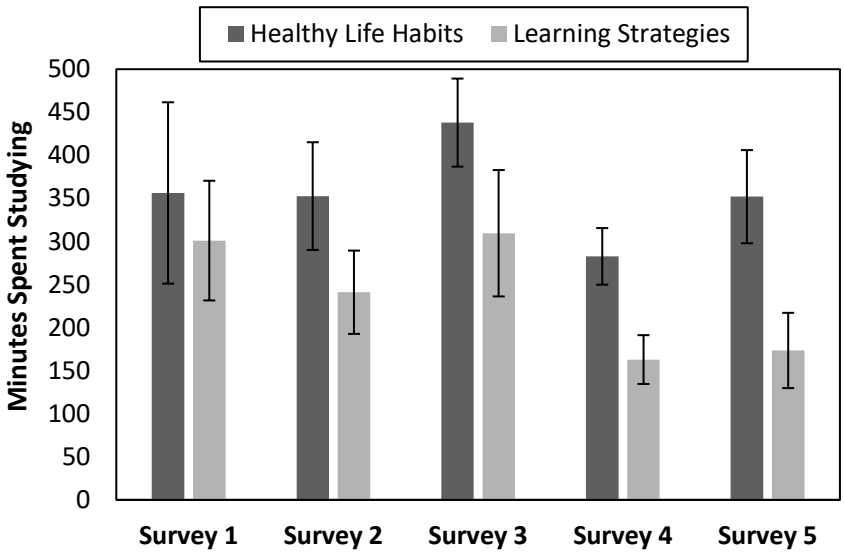

Figure 4. Proportion of students who reported using each strategy (averaged across the five surveys) by group assignment. Error bars reflect standard error of the mean.

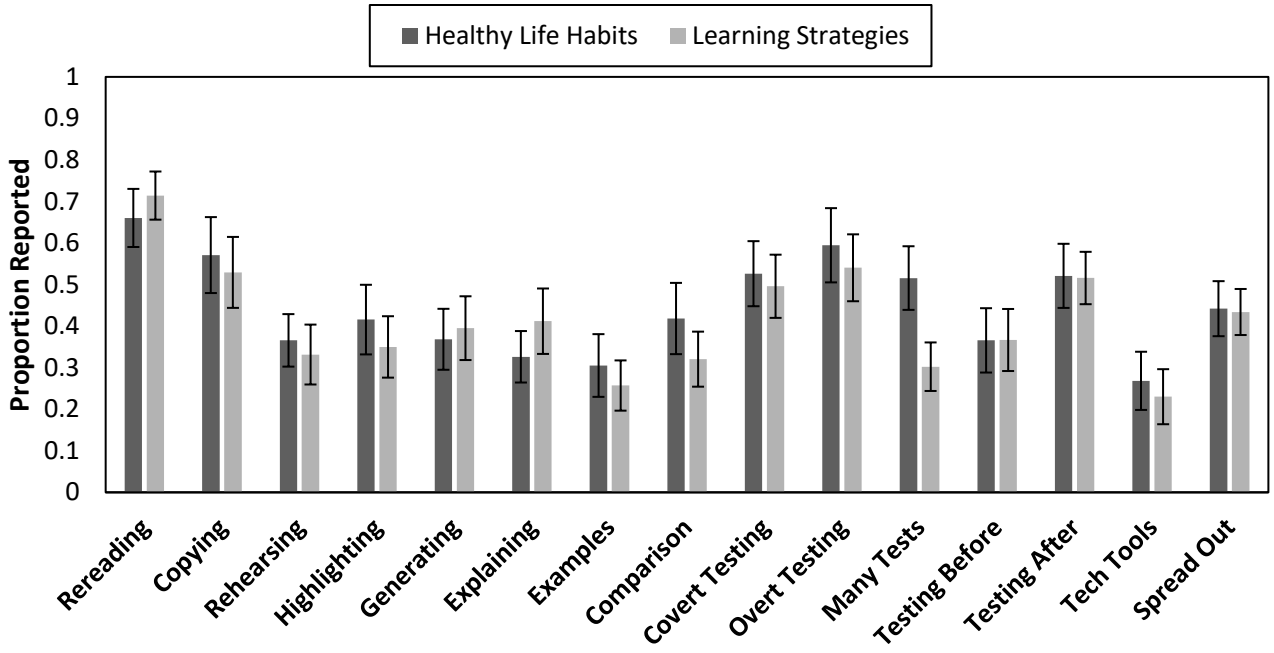

Figure 5. Exam performance for exams 1-4 and the final cumulative exam by group assignment. Error bars reflect standard error of the mean.