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Does Covert Prequestioning Enhance Learning? Implications for the Roles of Attention and Retrieval in the Prequestioning Effect

Michelle L. Rivers[1] | Ashley J. Berdelis[2] | Steven C. Pan[3] | Sarah K. Tauber[2]

[1]Santa Clara University, Santa Clara, California, USA | [2]Texas Christian University, Fort Worth, Texas, USA | [3]National University of Singapore, Queenstown, Singapore

Correspondence: Michelle L. Rivers (mrivers@scu.edu)

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ABSTRACT

Prequestioning, or attempting to answer questions before learning, can enhance memory relative to non-testing methods, in part by encouraging deeper processing of subsequent material. This study examined whether the benefits of prequestions depend on whether answers are typed (*overt prequestioning*) or mentally generated (*covert prequestioning*). Undergraduates read expository texts preceded by either overt or covert prequestions and were later tested with multiple-choice questions. Both formats improved performance relative to reading alone, with no reliable difference between covert and overt prequestioning. The similar efficacy of overt and covert prequestioning was replicated in a second experiment, which also found that prequestioning was just as effective as reviewing statements about what was to come before reading a passage. These findings suggest that prequestioning facilitates learning even without requiring overt responses, supporting theories that emphasize attentional focus. Thus, covert prequestioning offers a time-efficient, scalable strategy for improving comprehension and retention of textual information.

1 | Introduction

Instructors often begin lessons by asking students questions about the upcoming material, a practice known as *prequestioning*. For instance, before a lecture on Saturn, students might be asked, "How long does it take Saturn to revolve around the sun?" Even when students provide incorrect answers, they typically benefit more from the subsequent lesson than if no prequestions were posed. This phenomenon, known as the *prequestioning effect* (PE), highlights the advantages of engaging students early in the learning process (Carpenter et al. 2023; Pan and Carpenter 2023; St. Hilaire et al. 2024; Zhang and Fiorella 2023).

Evidence of the PE has been observed in studies such as Carpenter et al. (2018), where students answered prequestions before lessons. Compared to students who were not prequestioned, those who answered prequestions scored higher on post-lesson tests for prequestioned material—a *specific* benefit of prequestions. However, this advantage did not extend to new, unprequestioned material. That is, no *general* benefit of prequestioning was observed. Indeed, the PE's benefits are most pronounced for the memory of prequestioned content, with only some studies showing transfer to related information (e.g., Pan and Sana 2021).

The PE has been demonstrated across various educational materials (e.g., text passages, video lectures) and settings (e.g., classrooms, laboratories) using multiple test formats, including cued recall and multiple-choice (Carpenter and Toftness 2017; Richland et al. 2009; Pan and Sana 2021; Pan et al. 2025). Despite this, the role of *retrieval modality*—whether prequestions are answered overtly (e.g., written or verbal responses) or covertly (e.g., mental responses)—remains unexplored. This distinction has practical implications, as students can engage with prequestions covertly, such as when reading textbooks or participating in classroom activities where responses are not articulated by all students.

To address this gap, we investigated whether covert prequestioning enhances learning and how its effects compare to overt prequestioning. Clarifying the role of retrieval modality can provide insight into the cognitive mechanisms underlying the PE. Theoretically, prequestioning may promote learning by engaging retrieval processes, directing attention to relevant content, or a combination of both. Retrieval-based accounts (e.g., search set theory, Grimaldi and Karpicke 2012; reconsolidation theory, Metcalfe and Xu 2018; elaborative retrieval theory, Carpenter 2009) posit that prequestions activate prior knowledge and enrich the encoding of new information, enhancing memory through mechanisms such as semantic activation and the encoding of a rich episodic context, providing meaningful cues for future retrieval (e.g., through recursive reminding, Metcalfe and Huelser 2020). Alternatively, attentional accounts (e.g., answer search, Lewis and Mensink 2012, St. Hilaire and Carpenter 2020; attentional window, Sana and Carpenter 2023; mathemagenic hypothesis, Rothkopf 1966) argue that prequestions direct learners' focus to relevant material during learning, improving encoding through enhanced attention and increased curiosity.

Researchers have sought to disentangle the roles of retrieval and attention in the PE by comparing the impact of answering prequestions to activities designed to direct attention without triggering retrieval (e.g., memorizing prequestions, reading statements, or bolding key information; Beckman 2008; Little and Bjork 2011; Pressley et al. 1990; Richland et al. 2009; Schweppe et al. 2025; Sana et al. 2020, 2021). For instance, a meta-analysis by St. Hilaire et al. (2024) demonstrated a stronger PE in studies requiring answer generation ($g = 0.65$) compared to those involving only question reading ($g = 0.22$). Collectively, these findings highlight the contributions of both retrieval and attention to the PE.

The relative contributions of retrieval and attentional processes to the PE shapes predictions about covert prequestions. If retrieval drives the benefits of overt prequestions, covert prequestioning may be less effective. Research on overt versus covert *retrieval practice*, where participants are tested on material after initial learning (Roediger and Karpicke 2006), supports this distinction. For example, a recent meta-analysis by Yu et al. (2025) synthesized data from 18 studies involving 2560 participants and found that covert retrieval yielded modest learning gains compared to control strategies like rereading or restudy ($g = 0.23$). Moreover, overt retrieval provided an additional advantage over covert retrieval ($g = 0.17$). Yu and colleagues propose several explanations for this difference. First, covert retrieval may involve a truncated search process, where learners terminate their memory search earlier than they would when required to produce an overt response. Second, overt retrieval introduces a "desirable difficulty": its greater effort may slow learning initially but enhance long-term retention through deeper processing. Additionally, overt responses may increase exposure to correct information (Putnam and Roediger 2013), engage motor processes that create distinctive memory traces (i.e., the production effect; MacLeod et al. 2010), and better align with the cognitive and motor demands of later assessments (i.e., transfer-appropriate processing; Sundqvist et al. 2017). Applying these ideas, covert prequestions may not be as effective as overt prequestions, particularly if retrieval is the primary mechanism driving the PE.

In contrast, if the benefits of prequestions are primarily driven by attentional processes, then prequestioning may be similarly effective regardless of response format. Both overt and covert prequestions are likely to direct learners' attention to relevant material during subsequent reading.

To evaluate these predictions, we conducted a study with undergraduate students who read passages about Saturn and Yellowstone National Park. For one passage, students simply read the material (read-only condition). For the other passage, they answered short-answer prequestions either overtly (by typing responses) or covertly (by mentally answering) before reading (i.e., prequestions condition). Learning was measured on a subsequent multiple-choice test containing questions on both passages, and in the case of the prequestioned passage, questions that matched the prequestions (same questions) and entirely new questions drawn from the material (related questions). To gain further insights into participants' experiences and perceptions of the learning activities, we also collected metacognitive judgments—participants rated the perceived effectiveness of each learning strategy and provided open-ended explanations for their ratings.

We hypothesized that overt prequestioning would lead to higher test performance for same questions compared to the read-only condition, consistent with prior findings (e.g., Little and Bjork 2011; Pan and Sana 2021). For covert prequestioning, attentional theories suggest similar benefits to overt prequestioning, whereas retrieval-based theories predict smaller or no benefits. If the latter theories better explain the PE, however, then covert prequestions may fail to enhance learning for complex materials (i.e., text passages), showing reduced benefits compared to overt prequestions and limited transfer to related questions.

2 | Experiment 1

2.1 | Method

Both experiments were approved by Texas Christian University's Institutional Review Board, and all participants provided informed consent (and guardian consent was obtained for participants under 18 years). Item-level data and materials for this study are archived at the Open Science Framework (https://doi.org/10.17605/OSF.IO/GKJ8M). Experiment 1 was preregistered at https://doi.org/10.17605/OSF.IO/WNRFJ.

2.1.1 | Participants

Our target sample size was 176 participants (88 per group), with plans to oversample by up to 10% to account for potential exclusions based on predetermined criteria. We aimed to detect effects of at least moderate size, relevant to educational applications, and powered for a medium effect. An a priori power analysis using G*Power 3.1.9.7 (Faul et al. 2007) determined that a sample size of 176 would provide 95% power to detect a medium effect (Cohen's $d = 0.5$) with an alpha of 0.05 for a one-tailed independent samples *t*-test.

Due to a coding error, 16 participants (8 per group) were excluded after receiving prequestions for the wrong passage. An additional 14 participants (9 overt, 5 covert) were excluded due to computer errors or incomplete data.

The final sample included 165 undergraduate students (aged 16–39, $M = 19.70$, $SE = 0.16$) who participated for partial course credit. The sample was 72.7% women, 26.1% men, and 1.2% gender diverse. Racial/ethnic composition was 63% White, 13.9% Hispanic/Latine, 7.3% Black/African American, 6.1% Asian, and 9.7% mixed race/ethnicity.

2.1.2 | Design

Experiment 1 used a 2 (prequestion modality: overt vs. covert) × 3 (item type: same, related, read-only control) mixed-factor design. Prequestion modality was manipulated between participants, while item type was manipulated within participants. Participants were randomly assigned to either the overt prequestion group ($n = 82$) or the covert prequestion group ($n = 83$). Both groups also completed a read-only control learning activity.

2.1.3 | Materials

The materials consisted of two expository texts, each approximately 1100 words, on Yellowstone National Park and the planet Saturn (adapted from Pan and Sana 2021; originally developed by Little 2011). Each passage covered ten topics (e.g., Yellowstone: geysers, geothermal features, mammals) with 10 pairs of multiple-choice questions per passage. Questions in each pair tested the same topic but had different correct answers and identical response options. For example, for geysers, one question asked, "What geyser is thought to be the oldest in the world?" (Answer: Steamboat Geyser), while the other asked, "What is the tallest geyser in Yellowstone National Park?" (Answer: Castle Geyser). Although the answers to these questions entailed a single word or phrase, answering them could encourage retrieval of other, related information; moreover, the passages addressed relatively complex materials akin to those used in prior studies of covert retrieval practice.

For each passage, question pairs were divided into two 10-question sets (sets A and B). In the prequestions condition, participants were randomly pretested on either set A or set B using short-answer questions (counterbalanced across participants). Both sets were later included as multiple-choice items in the criterial test. "Same" questions were identical to those used in prequestioning (now in multiple-choice format), while "related" questions addressed the same topics but were not prequestioned, allowing investigation of the general benefit of prequestioning.

In the read-only control condition, participants did not answer prequestions before reading but were tested on all 20 multiple-choice questions for each passage during the criterial test.

2.1.4 | Procedure

Participants completed the experiment in small groups of up to eight, using computers programmed with Qualtrics. To begin, they rated their knowledge of Yellowstone National Park and Saturn on a 5-point scale ranging from "not knowledgeable at all" to "extremely knowledgeable." The order of the two topics was counterbalanced across participants. Across the two experiments, self-rated prior knowledge was low for both Yellowstone ($M = 1.79$, $SE = 0.04$) and Saturn ($M = 1.55$, $SE = 0.03$), with no significant differences between groups ($ps > 0.45$).

The experiment consisted of two cycles (illustrated in Figure 1), with cycle and passage order counterbalanced across participants. In both cycles, participants were instructed to "learn the information well because later in the study, you will take a multiple-choice test on the passage you read."

Each participant read two passages for at least 3 min each, one preceded by short-answer prequestions and one without (read-only control). Across the two experiments, participants spent an average of 280.96 s (4.68 min; $SE = 3.27$ s) reading each passage. In the prequestion condition, participants were told to answer the questions to the best of their ability, guess if unsure, and that there were no penalties for incorrect answers. Prequestions were presented one at a time in random order, with a minimum display time of 5 s before participants could proceed. Depending on group assignment, participants either typed their responses (overt group) or silently formulated answers without typing (covert group).

After reading each passage, participants completed a 5-min distractor task (playing Tetris) before taking a 20-question multiple-choice test on the passage. In the prequestion condition, half the test questions were identical to the prequestions (now with four response options), and the other half were related but not prequestioned. Test questions and response options were presented in random order. No corrective feedback was provided during prequestioning or the criterial test.

After completing both learning cycles, participants rated the effectiveness of answering questions before reading compared with reading without prequestions on a 5-point scale ranging from "not effective at all" to "extremely effective." They were also asked to explain their ratings. Finally, participants provided optional demographic information before being debriefed. The experiment took approximately 45 min for most participants to complete.

2.2 | Results and Discussion

We present results in the following order: criterial test performance, strategy effectiveness ratings, prequestion performance, and time spent answering prequestions. All analyses collapse

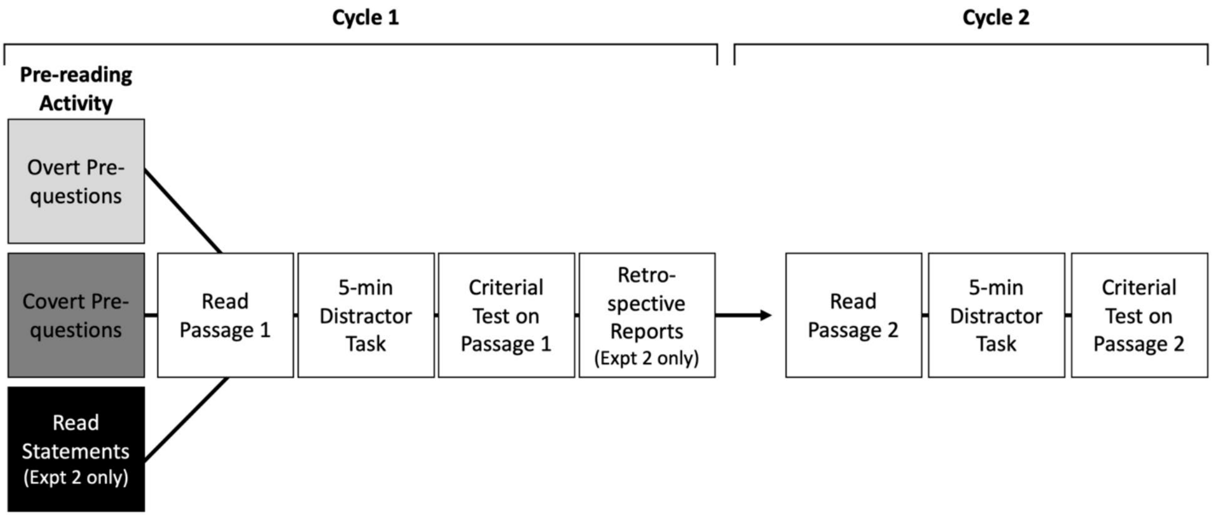

FIGURE 1 | Study procedure for Experiments 1 and 2. *Note*. All participants completed the two learning cycles. Passage order (Yellowstone or Saturn) and learning activity order (pre-reading activity or read-only control) were counterbalanced across participants. For simplicity, only one of two counterbalanced orders is shown. Expt = Experiment.

across counterbalancing conditions. Statistical tests are two-tailed unless specified otherwise, and effect sizes are based on Lakens (2013). We employed both frequentist and Bayesian approaches. The Bayesian analyses allowed us to compute Bayes factors, which quantify how much more likely the observed data are under the alternative hypothesis than under the null (see Kruschke 2013, for discussion). Bayes factors (BF_{10}) were computed using the *ttestBF* and *anovaBF* functions from the *BayesFactor* package in R (Morey and Rouder 2018), using default Cauchy priors. Values of BF_{10} greater than 1 indicate evidence favoring the alternative hypothesis, with 1–3 considered anecdotal, 3–10 moderate, and > 10 strong evidence. Values < 1 indicate evidence for the null, with 0.33–1 considered anecdotal, 0.10–0.33 moderate, and < 0.10 strong evidence. These Bayesian analyses were not preregistered and were conducted post hoc at the request of a reviewer to supplement the conventional frequentist tests.

2.2.1 | Criterial Test Performance

Figure 2 illustrates performance on the criterial multiple-choice test by item type and prequestion modality. Participants in both overt and covert groups performed better on same (prequestioned) items than on related or read-only items.

A 2 (prequestion modality: overt, covert) × 3 (item type: same, related, read-only) mixed ANOVA revealed a significant main effect of item type, $F(2, 326) = 31.60$, $p < 0.001$, $\eta^2_p = 0.16$ (same: $M = 0.54$, SE = 0.02, related: $M = 0.44$, SE = 0.02, read-only: $M = 0.42$, SE = 0.01). The main effect of modality was not significant, $F(1, 163) = 1.08$, $p = 0.30$, $\eta^2_p = 0.01$, nor was the interaction, $F(2, 326) = 1.16$, $p = 0.31$, $\eta^2_p = 0.01$. A Bayesian ANOVA converged with this pattern, providing decisive evidence for the effect of item type ($BF_{incl} = 1.78 \times 10^{10}$) and evidence in favor of the null hypothesis for both the prequestion modality main effect ($BF_{incl} = 0.22$) and the interaction ($BF_{incl} = 0.11$). Together, the Bayesian and frequentist analyses indicate that while performance differed reliably across item types, there was no evidence that prequestion modality influenced performance or moderated the item type effect.

Preregistered one-tailed paired *t*-tests revealed the following for the overt group: Same questions ($M = 0.51$, SE = 0.02) outperformed related questions ($M = 0.43$, SE = 0.02), $t(81) = 3.88$, $p < 0.001$, $g_{av} = 0.43$. Same questions also outperformed read-only items ($M = 0.42$, SE = 0.02), $t(81) = 3.95$, $p < 0.001$, $g_{av} = 0.50$. Related and read-only items did not significantly differ, $t(81) = 0.29$, $p = 0.20$, $g_{av} = 0.04$. Bayesian *t*-tests converged with this pattern, providing decisive evidence for higher performance on same than related items ($BF_{10} = 196.27$) and same than read-only items ($BF_{10} = 244.04$), and moderate evidence in favor of the null for the comparison between related and read-only items ($BF_{10} = 0.16$).

For the covert group: Same questions ($M = 0.56$, SE = 0.02) outperformed related questions ($M = 0.46$, SE = 0.02), $t(82) = 4.56$, $p < 0.001$, $g_{av} = 0.47$ and read-only items ($M = 0.42$, SE = 0.02), $t(82) = 7.00$, $p < 0.001$, $g_{av} = 0.75$. Related questions outperformed read-only items, $t(82) = 2.30$, $p = 0.01$, $g_{av} = 0.23$. Bayesian *t*-tests supported these findings, providing decisive evidence for higher performance on same than related items ($BF_{10} = 1948.30$) and same than read-only items ($BF_{10} = 3.19 \times 10^7$), and moderate evidence for higher performance on related compared to read-only items ($BF_{10} = 2.87$).

Thus, prequestions were more effective than simply reading, regardless of whether they were answered overtly or covertly. Both overt and covert prequestioning yielded better criterial test performance on the same questions than the read-only control, and in the case of covert prequestioning, significantly better performance on related questions as well.

2.2.2 | Strategy Effectiveness Ratings

A 2 (prequestion modality) × 2 (strategy: prequestioning, reading) mixed ANOVA revealed a main effect of strategy, with

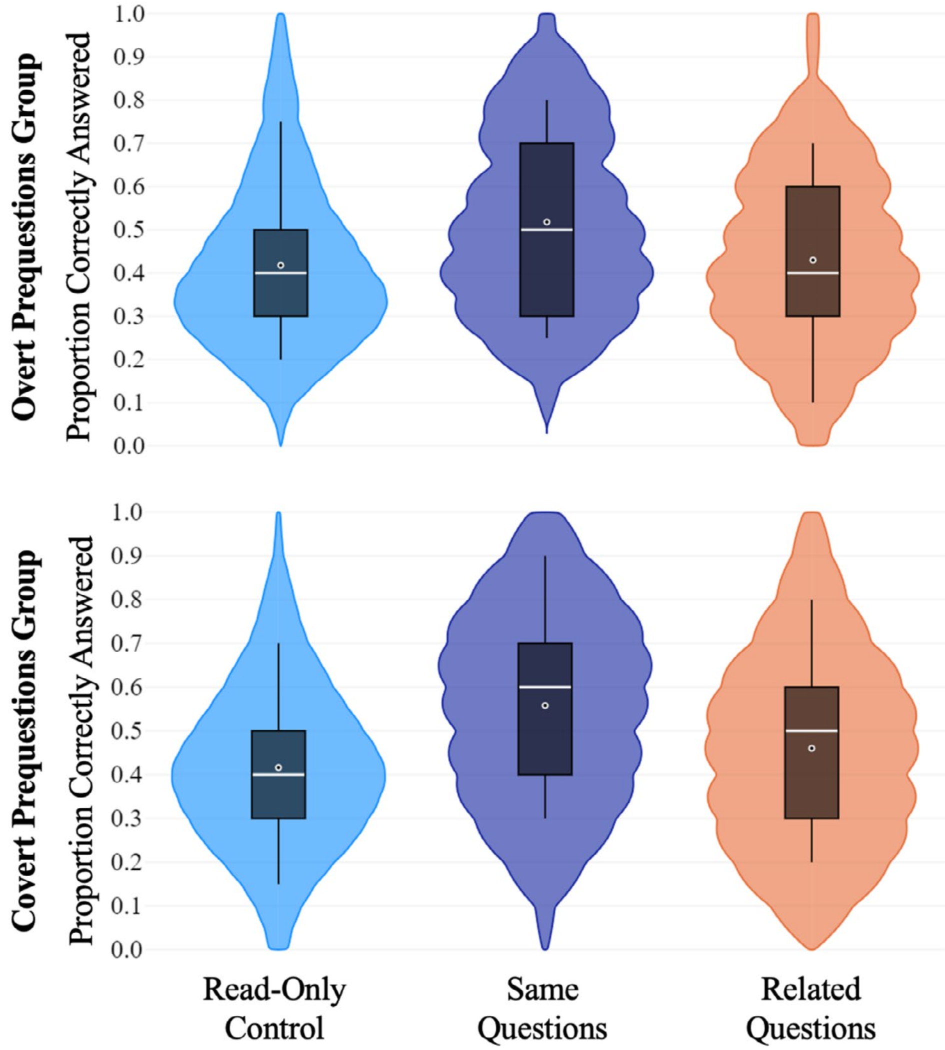

FIGURE 2 | Criterial test performance on read-only, same, and related items for the overt prequestions group (top) and the covert prequestions group (bottom) in Experiment 1. *Note*. Violin plots with embedded box plots of the proportion of questions correctly answered on the criterial multiple-choice test as a function of item type and prequestion modality in Experiment 1. The mean for each item type is marked with a circle.

higher ratings for prequestioning ($M = 3.29$, $SE = 0.09$) than reading ($M = 2.20$, $SE = 0.08$), $F(1, 163) = 68.31$, $p < 0.001$, $\eta^2_p = 0.30$, $BF_{incl} = 2.00 \times 10^{15}$. The main effect of group and the interaction were not significant (*p*s > 0.60), and the Bayesian analysis provided moderate evidence for the null for both effects ($BF_{incl} < 0.11$).

Overall, 69% of participants rated prequestioning as more effective, 16% preferred reading, and 15% reported no difference. Explanations for ratings were coded into five categories (Table 1). Most responses (73.3%) indicated that prequestions helped learners prepare for reading.

2.2.3 | Performance on Prequestions

Prequestion responses were scored manually, accepting minor spelling errors. Performance in the overt group was very low ($M = 0.04$, $SE = 0.01$) and did not differ between the two passages, $t(80) = 0.03$, $p = 0.98$, $BF_{10} = 0.23$.

2.2.4 | Time Spent Answering Prequestions

The overt group spent more time per prequestion ($M = 12.78$ s, $SE = 0.57$) than the covert group ($M = 8.21$ s, $SE = 0.24$), $t(163) = 7.36$, $p < 0.001$, $g_s = 1.14$, $BF_{10} = 8.35 \times 10^8$. Given that criterial test performance did not differ by group, covert pretesting may be more time-efficient.

3 | Experiment 2

In Experiment 1, both overt and covert prequestion groups performed significantly better on prequestioned material than the read-only control group. Experiment 2 replicated this advantage and more directly examined the effectiveness of covert pretesting by comparing overt prequestioning (which involves overt retrieval) and covert prequestioning to an alternative pre-reading activity: reading learning objectives—defined as brief statements that specify the knowledge students should acquire by the end of a study session (Sana et al. 2020). Prior work suggests that

TABLE 1 | Percent of participants whose rating responses fell into each category by group in Experiments 1 and 2.

	Prequestions helped prepare for reading	Focused only on prequestioned material	Prequestions were confusing or impossible	Rating based on memory or test performance	Other
Experiment 1					
Overt prequestions group	62.2%	3.7%	11.0%	9.8%	24.4%
Covert prequestions group	68.7%	3.6%	9.6%	9.6%	19.3%
Experiment 2					
Overt prequestions group	72.55	3.7%	2.8%	12.8%	17.4%
Covert prequestions group	75.6%	3.4%	5.0%	13.4%	16.8%
Read statements group	71.35%	3.4%	3.4%	5.7%	23.0%

Note: After participants rated the effectiveness of the two learning strategies, they were asked to explain why they made the ratings that they did. Responses were coded into categories; responses could fall into multiple categories. Two independent raters agreed on 87.0% of responses; disagreements were resolved by the first author.

such objectives can modestly enhance learning, likely by directing attention to relevant content (without inducing retrieval attempts). One meta-analysis reported a small-to-medium benefit of learning objectives (broadly defined) over control conditions for information they directly target ($d = 0.40$; Klauer 1984).

Prior research by Sana et al. (2020, Experiment 2) compared learning objectives and prequestions (multiple-choice questions without feedback) for learning a neuroscience passage. They found that prequestioning led to significantly greater learning gains than simply reading the learning objectives ($d = 0.84$), and no significant difference between the learning objectives and statements including the answers. Similarly, Beckman (2008) compared two sections of a freshman-level Introduction to Aerospace course and reported that the section receiving prequestions before each unit performed significantly better on tests than a section presented with learning objectives (with *d*s ranging from 0.53 to 0.80). More recently, Schweppe et al. (2025) found that prequestions yielded modest but reliable learning benefits compared to both reading-only (with *d*s ranging from 0.31 to 0.66) and learning-objective control conditions (with *d*s ranging from 0.26 to 0.37), with advantages limited to information directly queried. Building on this work, Experiment 2 tested whether *covert* prequestioning would similarly outperform passive reading of key information prior to reading.

To further explore the processes underlying covert and overt prequestioning, we introduced an exploratory measure inspired by retrieval practice research (e.g., Robey 2019). After completing the criterial test, participants in the pre-reading activity condition completed a retrospective report questionnaire. For each question or statement encountered during the pre-reading activity, participants selected from a set of responses describing what they did during that activity.

3.1 | Method

Experiment 2 was preregistered at https://doi.org/10.17605/OSF.IO/Q3FM5.

3.1.1 | Participants and Design

Our target sample size was 264 participants (88 per group, as in Experiment 1). Due to an unfortunate coding error, 22 participants in the read statements group were excluded because they could not complete retrospective reports in the pre-reading activity condition. An additional 11 participants were excluded due to computer errors or failure to complete the experiment (4 from the overt group, 2 from the covert group, and 5 from the read statements group).

The final sample consisted of 315 students from Texas Christian University, who participated for partial course credit. Participants ranged from 18 to 40 years old ($M = 19.55$, $SE = 0.10$). The sample included 81.3% women and 18.7% men, with the following racial/ethnic composition: 71% White, 10.2% Hispanic/Latine, 6.7% Asian, 2.9% Black/African American, and 9.2% mixed race or ethnicity.

Experiment 2 used a 3 (pre-reading activity: overt prequestions, covert prequestions, read statements) × 3 (item type: same, related, read-only control) mixed design. Pre-reading activity was manipulated between participants, while item type was manipulated within participants. Participants were randomly assigned to one of the three groups: overt prequestions ($n = 109$), covert prequestions ($n = 119$), or read statements ($n = 87$).

3.1.2 | Procedure

Experiment 2 followed the same procedure as Experiment 1, with two key differences (see Figure 1).

First, a third between-participants group was introduced: the read statements group. Participants in this group were presented with statements outlining key information they would encounter in the upcoming passage. For example, while the overt prequestion group was asked, "Provide your answer to the question below: What planet lacks an internal magnetic field?," the corresponding statement for the read statements group was, "While reading the passage, you will learn: The planet that lacks an internal magnetic field." Participants in the read statements group were required to view each statement for at least 5 s.

Second, all participants completed retrospective reports after the criterial test for the passage that was preceded by (overt or covert) prequestions or reading statements. Participants were reminded that they had previously encountered practice questions (or statements) and were asked to reflect on their initial engagement with them. For each pre-reading question or statement, participants chose one of seven response options describing their primary approach:

1. Read: "I read the question/statement but didn't think of anything, or thought I didn't know."
2. Memorize: "I tried to memorize part or all of the question/statement."
3. Respond: "I came up with a response to the question/statement."
4. Thought of Idea: "I thought of an idea or ideas related to the question/statement, such as something I had previously seen, read, or heard."
5. Mental Image: "I developed a mental image or picture related to the question/statement."
6. Something Else: "I did something else not described above."
7. Don't Remember: "I don't remember what I did for this question/statement."

These additions allowed for deeper exploration of participant engagement during pre-reading activities and potential differences between groups.

3.2 | Results and Discussion

3.2.1 | Criterial Test Performance

Figure 3 depicts performance on the criterial multiple-choice test by item type and pre-reading activity group. Across all groups, participants performed better on the same questions compared to related and read-only questions.

A 3 (pre-reading activity group: overt prequestions, covert prequestions, read statements) × 3 (item type: same, related, read-only control) mixed ANOVA revealed a significant main effect of group, $F(2, 312) = 4.38$, $p = 0.013$, $\eta^2_p = 0.03$ (overt: $M = 0.55$, $SE = 0.01$; covert: $M = 0.49$, $SE = 0.01$; statements: $M = 0.51$, $SE = 0.02$). However, the corresponding Bayesian analysis provided only anecdotal evidence for this effect ($BF_{incl} = 1.20$). The main effect of item type was also significant, $F(2, 624) = 57.20$, $p < 0.001$, $\eta^2_p = 0.16$ (same: $M = 0.59$, $SE = 0.01$; related: $M = 0.50$, $SE = 0.01$; read-only: $M = 0.46$, $SE = 0.01$), and the Bayesian analysis provided decisive evidence for this effect ($BF_{incl} > 10^{15}$). The interaction was not significant, $F(4, 624) = 0.37$, $p = 0.83$, $\eta^2_p = 0.002$, and the Bayesian analysis likewise indicated strong evidence for the null ($BF_{incl} = 0.02$).

We conducted one-tailed *t*-tests for the three groups. For the overt group, performance was higher for same questions ($M = 0.62$, $SE = 0.02$) compared to related questions ($M = 0.53$, $SE = 0.02$), $t(108) = 4.14$, $p < 0.001$, $g_{av} = 0.45$, $BF_{10} = 501.83$. Performance for same questions was also higher than for the read-only control ($M = 0.49$, $SE = 0.02$), $t(108) = 6.83$, $p < 0.001$, $g_{av} = 0.73$, $BF_{10} = 3.64 \times 10^7$. Finally, related questions outperformed the read-only control, $t(108) = 2.14$, $p = 0.02$, $g_{av} = 0.23$, $BF_{10} = 1.85$.

For the covert group, performance was higher for same questions ($M = 0.57$, $SE = 0.02$) compared to related questions ($M = 0.48$, $SE = 0.02$), $t(118) = 3.92$, $p < 0.001$, $g_{av} = 0.44$, $BF_{10} = 235.81$. Same questions also outperformed the read-only control ($M = 0.43$, $SE = 0.02$), $t(118) = 7.76$, $p < 0.001$, $g_{av} = 0.71$, $BF_{10} = 4.57 \times 10^9$. Finally, related questions outperformed the read-only control, $t(118) = 2.48$, $p = 0.01$, $g_{av} = 0.26$, $BF_{10} = 3.77$.

For the statements group, performance was higher for same questions ($M = 0.57$, $SE = 0.02$) compared to related questions ($M = 0.48$, $SE = 0.02$), $t(86) = 3.62$, $p < 0.001$, $g_{av} = 0.44$, $BF_{10} = 88.02$. Same questions also outperformed the read-only control ($M = 0.46$, $SE = 0.02$), $t(86) = 4.95$, $p < 0.001$, $g_{av} = 0.57$, $BF_{10} = 8362.39$. Performance did not differ for related questions compared to the read-only control, $t(86) = 0.97$, $p = 0.17$, $g_{av} = 0.10$, $BF_{10} = 0.31$.

3.2.2 | Strategy Effectiveness Ratings

A 3 (activity group) × 2 (strategy: pre-reading activity, reading) mixed ANOVA revealed a main effect of group, $F(2, 312) = 6.01$, $p = 0.003$, $\eta^2_p = 0.04$ (overt: $M = 2.91$, $SE = 0.06$; covert: $M = 2.69$, $SE = 0.06$; statements: $M = 2.64$, $SE = 0.06$), although the Bayesian analysis provided only anecdotal evidence for this effect ($BF_{incl} = 0.75$). The main effect of strategy was also significant, with participants rating the pre-reading activity ($M = 3.38$, $SE = 0.06$) as more effective than reading alone ($M = 2.11$, $SE = 0.05$), $F(1, 312) = 213.86$, $p < 0.001$, $\eta^2_p = 0.41$, and the Bayesian analysis provided decisive evidence for this effect ($BF_{incl} = 6.00 \times 10^{15}$). The interaction was not significant, $F(2, 312) = 0.25$, $p = 0.78$, $\eta^2_p = 0.002$, and the Bayesian analysis likewise indicated strong evidence for the null ($BF_{incl} = 0.10$).

Most participants (79%) rated pre-reading activities as more effective than reading, with explanations (coded into five categories, Table 1) showing that 65.5% of responses indicated prequestions or statements helped prepare them for reading.

3.2.3 | Performance on Prequestions

Prequestion performance in the overt group was low ($M = 0.05$, $SE = 0.01$), with no significant difference between the Yellowstone and Saturn passages, $t(107) = 0.52$, $p = 0.60$, $BF_{10} = 0.24$.

3.2.4 | Retrospective Reports

All participants completed retrospective reports for the 10 pre-reading questions or statements, yielding 3150 responses. On average, participants made 3.32 ($SE = 0.07$) unique responses

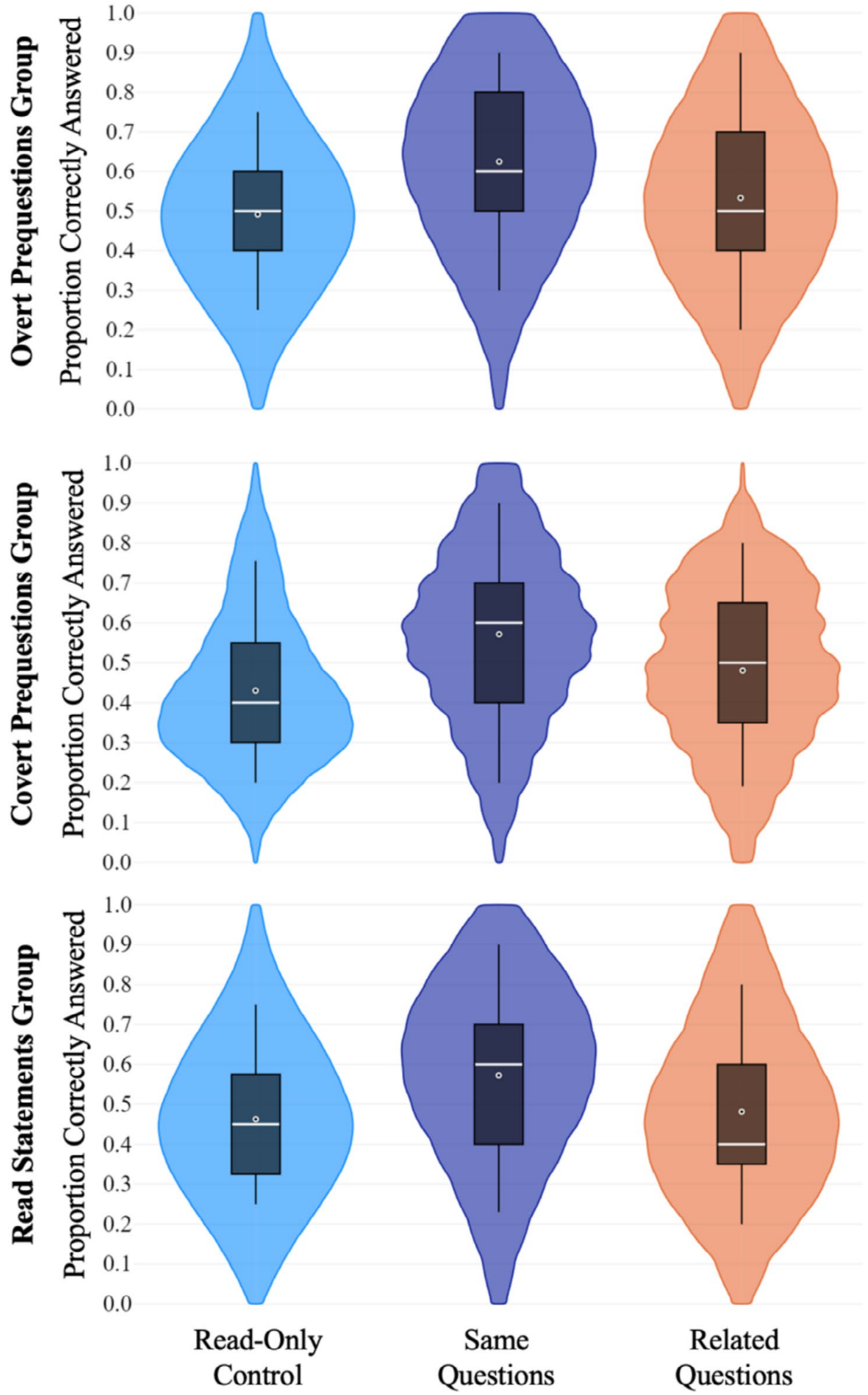

FIGURE 3 | Criterial test performance on read-only, same, and related items for the overt prequestions group (top), the covert prequestions group (middle), and the read statements group (bottom) in Experiment 2. *Note*. Violin plots with embedded box plots of the proportion of questions correctly answered on the criterial multiple-choice test as a function of item type and pre-reading activity in Experiment 2. The mean for each item type is marked with a circle.

across the 10 questions or statements, and this value did not significantly differ across groups, $F(2,\ 312)=1.91$, $p=0.15$, $\eta^2_p=0.01$, $BF_{incl}=0.50$.

As shown in Figure 4, for the overt group, the most common response was "read", whereas for the covert and read statements groups, the most common response was "memorize."

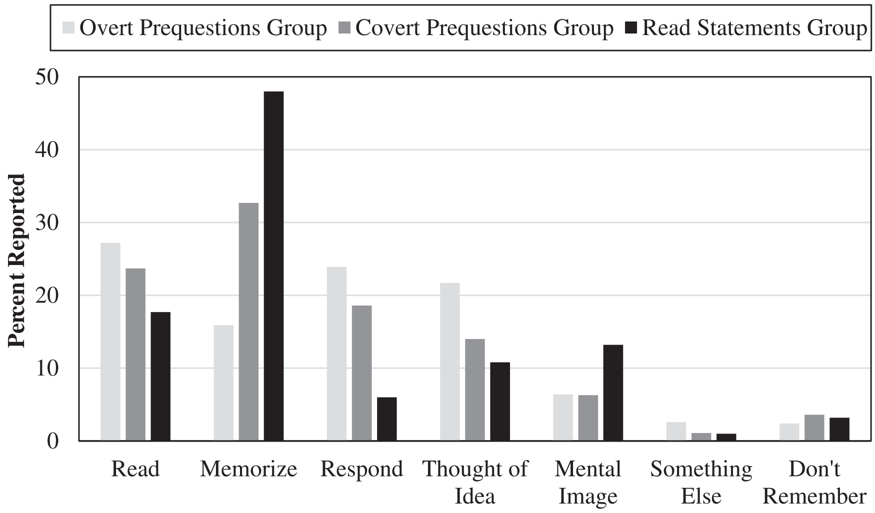

FIGURE 4 | Percent of retrospective reports by pre-reading activity group. *Note*. Refer to the method of Experiment 2 for a full description of response options.

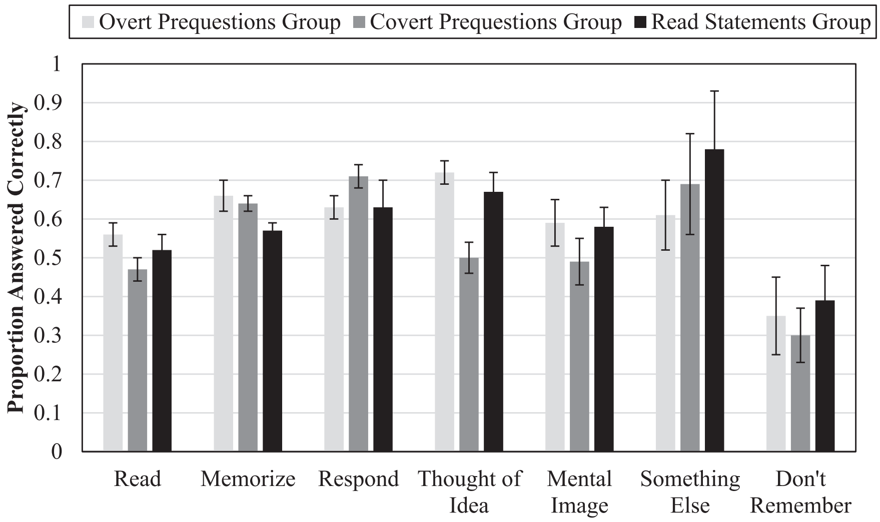

FIGURE 5 | Performance on criterial test by retrospective report and pre-reading activity group. *Note*. Refer to the method of Experiment 2 for a full description of response options.

Performance on the criterial test by retrospective report and group is shown in Figure 5.

While these self-reports offer useful insight into participants' subjective experiences, they are inherently limited by introspective bias. Future work incorporating more direct process-tracing methods, such as eye-tracking or think-aloud protocols (cf. Yang et al. 2021), may provide a more objective lens into the cognitive processes at play.

3.2.5 | Time Spent on Pre-Reading Activities

A one-way ANOVA revealed significant differences in time spent on pre-reading activities between groups, $F(2, 312) = 86.41$, $p < 0.001$, $\eta^2_p = 0.36$, $BF_{incl} > 10^{15}$. Independent-samples *t*-tests revealed that the overt group ($M = 15.43$ s, $SE = 0.43$) spent more time than the covert group ($M = 8.99$ s, $SE = 0.41$), $t(226) = 9.53$, $p < 0.001$, $g_s = 1.26$, $BF_{10} = 1.64 \times 10^{15}$, and the statements group ($M = 7.88$ s, $SE = 0.48$), $t(194) = 11.32$, $p < 0.001$, $g_s = 1.62$, $BF_{10} = 7.66 \times 10^{19}$. The covert group also spent more time than the statements group, $t(204) = 2.27$, $p = 0.024$, $g_s = 0.32$, $BF_{10} = 1.67$.

4 | General Discussion

Across two experiments, we found strong support for the prequestioning effect (PE): learners who answered prequestions, whether overtly or covertly, outperformed those who only read the text, suggesting that prequestioning enhances learning even without articulated responses. An important consideration for educational practice is the efficiency of different pre-reading strategies. In both experiments, participants in the covert prequestion group consistently spent less time on the pre-reading task than those in the overt group, yet achieved comparable performance on the criterial test. This pattern suggests that covert prequestioning may offer a more time-efficient approach to enhancing learning from text.

Our findings contribute to ongoing theoretical debates about the mechanisms underlying the PE. Retrieval-based accounts propose that attempting to retrieve information activates related prior knowledge and enriches encoding, whereas attentional accounts emphasize the role of prequestions in directing focus to relevant content. The similar performance between overt and covert prequestion conditions seems to favor attentional explanations, especially given retrospective reports indicating that learners often mentally engaged with the questions even without typing responses (Figure 4).

However, our findings do not rule out retrieval-based accounts of the prequestioning effect. If overt and covert prequestions produce comparable learning outcomes, one possibility is that both formats engage retrieval processes or activate related prior knowledge to a similar extent. Another possibility is that different pre-reading activities influence learning through distinct but not mutually exclusive cognitive pathways. For example, attempting to answer a prequestion could activate prior knowledge, whereas simply reading or attempting to memorize a question might enhance attention to key ideas in the text. In fact, our retrospective data suggest that covert participants were more likely than overt participants to report memorizing the question itself, pointing to possible differences in how each group engaged with the material.

Alternatively, the materials used in our experiments (factual expository texts) may not have been well-suited to highlight differences in the depth of elaboration or cognitive effort elicited by overt versus covert prequestioning. Prior research on retrieval practice suggests that the relative effectiveness of covert retrieval depends on the demands of the retrieval task. For simple materials that require only one unit to be retrieved, such as paired associates, covert and overt retrieval tend to yield similar benefits (Jönsson et al. 2014; Putnam and Roediger 2013; Smith et al. 2013; Sundqvist et al. 2017). In contrast, for more complex materials like definitions that require multiple units to be retrieved, overt retrieval often leads to superior learning (Rivers et al. 2025; Sumeracki and Castillo 2022; Tauber et al. 2018). Thus, we hope this research motivates future studies to use more conceptually rich or generative materials that may more effectively reveal how different retrieval mechanisms contribute to the relative effectiveness of overt versus covert prequestioning.

The PE was strongest for same items (i.e., those that directly matched prequestions), but we also observed modest benefits for related questions in both prequestion conditions. These findings suggest limited generalization of the prequestioning advantage to unprequestioned content, aligning with prior research showing that such transfer is typically constrained by semantic relatedness and engagement depth.

Interestingly, our findings contrast with previous studies using simpler materials (e.g., paired associates), which have shown that learners often underestimate the benefits of errorful generation and pretesting (e.g., Huelser and Metcalfe 2012; Pan and Rivers 2023; Pan et al. 2020). In our study, participants tended to rate prequestioning as more effective than reading, suggesting that learners may be more attuned to the benefits of prequestioning when interacting with richer, text-based materials.

Overall, this research expands our understanding of the PE by showing that covert prequestioning (mentally answering questions without written responses) can be as effective as overt responding. Our findings suggest that multiple cognitive mechanisms, such as retrieval, prior knowledge activation, and attentional focus, may work in tandem, with their relative contributions depending on task demands and learner strategies. Given its flexibility and ease of implementation, prequestioning remains a promising tool for promoting deeper learning across diverse educational contexts.

Author Contributions

Michelle L. Rivers: conceptualization, investigation, writing – original draft, methodology, validation, visualization, writing – review and editing, software, formal analysis, project administration, data curation, supervision. **Ashley J. Berdelis:** funding acquisition, conceptualization, investigation, methodology, writing – review and editing, writing – original draft, formal analysis, data curation. **Steven C. Pan:** investigation, conceptualization, methodology, writing – review and editing. **Sarah K. Tauber:** writing – review and editing, investigation, conceptualization, methodology, validation, supervision.

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Ethics Statement

The materials and methodology for this study were approved by the Institutional Review Board (IRB) of Texas Christian University (IRB approval number: 1709-014-1709 AM2).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in Open Science Framework at https://osf.io/gkj8m/, reference number 10.17605/OSF.IO/GKJ8M.

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