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Empirical article

The Dark Side of Interpolated Testing: Frequent Switching Between Retrieval and Encoding Impairs New Learning☆

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Practicing retrieval can improve the updating or modification of existing knowledge. When students need to update their existing knowledge, performing retrieval practice on the first set of materials often strengthens learning of the next set. However, Davis and Chan (2015) reported that interpolated testing can sometimes impair new learning. Here, we examined whether frequently switching between retrieval of previously learned material and encoding of new material can disrupt learning of the new material. In the current experiment, participants either switched between restudying originally learned items and new learning or between retrieving originally learned items and new learning, and we varied the frequency with which task switching occurred. We found that interpolating retrieval, but not restudy, with new learning impaired new learning. These results are consistent with the idea that retrieval practice and encoding rely on different cognitive processes, and intermixing them can exert a cost.

General Audience Summary

New learning must be scaffolded onto previously learned concepts, and some research has shown that recalling previously learned information (i.e., retrieval practice) can aid later learning of new concepts. However, other research has found the opposite effect. Here, we examined when and why retrieval practice can enhance or impede new learning. We hypothesized that retrieval practice is harmful to new learning when learners must frequently switch between retrieving old materials and learning new ones. We asked participants to remember two sets of materials that were associated with the same concept, and found that retrieving materials from the first set enhanced learning of the new set when retrieval practice and new learning occurred in separate phases of the experiment. However, when retrieval practice and new learning were intermixed in a single phase of the experiment, retrieval (as opposed to reviewing previously learned concepts) impaired new learning. We suggest that retrieval uses different mental processes than those necessary for learning new information, and frequently switching between these processes can interfere with new learning. We conclude by recommending that instructions provide in-class quiz questions at the beginning or end of a class to minimize these interfering effects of retrieval, while still reaping its benefits.

Keywords: Testing effect, Interpolated testing, Test-potentiated learning, Retrieval, Task-switching

Effective learning involves not only retaining information (e.g., students may see a picture of the hippocampus and must remember its shape or location in association with its name), but updating existing knowledge with new information (e.g., the functions of various areas of the hippocampus). Knowledge updating is particularly important in learning STEM concepts at the university level. For example, students may need to first master the simpler concepts in general biology and later update their

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knowledge by learning the more complex processes like gene expression (Jensen, Kummer, & Banjoko, 2013). As such, an important goal in educational research is to identify techniques that can aid in both retention and knowledge updating.

Retrieval practice (or testing) is one of the most effective techniques for boosting learning. In the present paper, we focus on the finding that testing can potentiate new learning that occurs later (Pastötter & Bäuml, 2014; Szpunar, McDermott, & Roediger, 2008; Wissman, Rawson, & Pyc, 2011). This benefit of testing has important educational implications, as performing retrieval practice on previously learned information may facilitate knowledge updating. To this end, researchers have argued that interspersing a lecture with brief memory tests can facilitate learning in the classroom (Szpunar, Khan, & Schacter, 2013). However, and of critical interest to the present study, interspersing retrieval practice trials into an encoding phase has also been shown to impair new learning (Davis & Chan, 2015; Finn, 2017; Finn & Roediger, 2013).

In a series of experiments, Finn and Roediger (2013) demonstrated that performing retrieval practice can impair new learning in a memory updating paradigm. Specifically, participants first studied a set of face–name pairs–the original learning (*OL*) items. During the intermediate phase, participants either restudied a face–name pair or recalled the name when given the face (before receiving feedback). Following this restudy or test trial, participants must update their knowledge of the face by learning the profession for that face–the new learning (*NL*) items. Surprisingly, initial testing of the OL association impaired subsequent learning of the NL association.

In a subsequent study, Davis and Chan (2015) argued that testing impaired new learning in Finn and Roediger's (2013) paradigm because intermixing retrieval practice and new learning trials might have encouraged participants to prioritize restudying the OL items ahead of learning the NL items. This bias could occur because the test reveals to participants the difficulty associated with learning the OL item, and because the corrective feedback for the OL item is presented just before the NL item was presented. Consequently, participants might "borrow time" from the NL trial to study the OL item. Critically, this bias in relearning the OL items is absent when participants restudy the OL association, because they would not realize the difficulty associated with learning the OL association through restudy trials. Moreover, this bias in relearning the OL item is also absent in procedures that have typically demonstrated test-potentiated new learning, in which the retrieval practice trials and the new learning trials are presented in separate trial blocks (Pastötter & Bäuml, 2014; Szpunar et al., 2013; Weinstein, McDermott, & Szpunar, 2011; Wissman et al., 2011).

These opposite effects of retrieval on new learning pose interesting questions for educational practice. For example, how often and when should instructors interpolate questions in a lecture to maximize their benefits and minimize their costs? From a theoretical perspective, it is important to examine the processes by which interpolated retrieval impairs new learning. Although Davis and Chan (2015) provided evidence that supports the metacognitive bias account, their manipulations, which were aimed at removing the bias on relearning the OL items, never resulted in the test-potentiated new learning effect. Instead, these manipulations either reduced or eliminated the test-impaired new learning effect (see their Experiments 2, 3, and 5).

In the present study, we consider the possibility that repeatedly switching between retrieval (relative to restudy) of OL items and encoding of NL items can impair new learning (see also Finn, 2017). This hypothesis stems from the cognitive control literature, wherein participants who alternate between two incompatible task sets often show impaired performance on one or both tasks (Allport, Styles, & Hsieh, 1994; Pashler, Johnston, & Ruthruff, 2001). Switching between two tasks requires participants to exert top-down control to reconfigure the task set (Baddeley, Chincotta, & Adlam, 2001; Logan & Gordon, 2001; Meiran, 1996), and the effort required to switch between incompatible tasks incurs a *switch cost* (Monsell, 2003; Rogers & Monsell, 1995; Sudevan & Taylor, 1987). For example, participants might be shown a series of digits, and must switch between indicating whether the number is even or odd in one trial and whether it is less than or greater than five in the next trial. Repeatedly switching between these incompatible tasks often degrades performance. The cost of task switching is manifested by poorer accuracy and/or slower reaction times on *switch trials* (e.g., trials preceded by a different task) relative to *stay trials* (e.g., consecutive trials of the same task). Applying this logic to the present context, requiring learners to switch between retrieval practice of OL items and encoding of NL items might elicit a switch cost, which could in turn impair new learning.

This proposition is supported by data suggesting that encoding and retrieval are subserved by different neural mechanisms. Tulving (1983) proposed the concept of *retrieval mode*, an active process of episodic remembering that occurs when individuals think back to previous experiences, which involves different processing demands than encoding. This idea is buttressed by neuroimaging evidence that shows that retrieval is right-lateralized and encoding is left-lateralized in the prefrontal cortex (e.g., Düzel, 2000; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994), and that retrieval and encoding employ different networks of the hippocampal formation (Duncan, Tompary, & Davachi, 2014).

A closer examination of Davis and Chan's (2015) data provides preliminary support for the task switch hypothesis. For example, Davis and Chan found that increasing the feedback duration associated with the OL item for a few seconds before encoding of the NL item decreased the magnitude of the test-impaired new learning effect (Experiment 2). This is similar to an established finding in the task-switching literature, in which switch costs are reduced when preparation time is increased (Meiran, 1996). Moreover, presenting the OL items and NL items in separate trial blocks led to test-potentiated new learning (Experiment 4). It is important to note here that the metacognitive bias account proposed by Davis and Chan and the task-switching account proposed here are not mutually exclusive, and both processes could contribute to the test-impaired new learning effect.

To test the possibility that switching between retrieval of studied information and encoding of new information may impair

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