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The importance of constructive comprehension processes in learning from tests

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ABSTRACT

The goal of these experiments was to introduce and test the constructive retrieval hypothesis, according to which retrieval practice will be most effective when it encourages constructive elaborations of text content. Experiment 1 provided baseline performance data for the materials included in Experiments 2 and 3. In Experiment 2, instilling inference-based test expectancies before an initial retrieval attempt led to more constructive retrieval practice and better final test performance than instilling detail-based expectancies. In Experiment 3, instructions to construct explanations during initial retrieval attempts led to more constructive retrieval practice than free recall, and better final test performance than free recall or rereading instructions. These experiments support a constructive retrieval account of testing effects, and demonstrate that it is not retrieval practice alone, but rather the kind of constructive processing invoked during retrieval attempts that can improve both retention and comprehension when learning from text.

Introduction

The idea that simply testing one's own memory can serve as an effective learning activity is an appealing one and recent research among cognitive psychologists suggests that retrieval practice may indeed be useful (see Roediger & Karpicke, 2006a, for a review). The advantage of testing over a re-study opportunity has been designated the "testing effect" and evidence for this advantage has been cited as a reason to increase the frequency of testing in classrooms (McDaniel, Roediger, & McDermott, 2006; Pashler et al., 2007; Roediger, Agarwal, Kang, & Marsh, 2010).

The term "testing effect" requires clarification, however, as there can be many effects of tests (see Crooks, 1988), from shaping future study (Mawhinney, Bostow, Laws, Blumenfeld, & Hopkins, 1971; Szpunar, McDermott, & Roediger, 2008), to inducing anxiety (Hembree, 1988), to allowing for feedback (Butler & Roediger, 2008) and formative interventions (Black & Wiliam, 1998; Wiliam, 2007). What is at issue in research on the testing effect is not simply whether tests can be useful in learning contexts. Rather, proponents of applying testing effects in classrooms suggest a more uncommon claim: testing is a useful mnemonic device because the act of retrieving information from memory has a direct effect on the later retrievability of that information (see Karpicke & Roediger, 2007). Intriguingly, these direct effects, referred to as *retrieval practice* effects, are often robust, even without feedback or restudy opportunities (Carpenter, Pashler, & Vul, 2006; Hinze & Wiley, 2011; Roediger & Karpicke, 2006b).

Recently, research has focused on the more difficult questions of *when* and *why* retrieval practice may enhance retention (Carpenter, 2009; Pyc & Rawson, 2010), and *when* and *why* retrieval practice may influence comprehension or conceptual understanding, as demonstrated on final tests requiring transfer (Butler, 2010; Johnson & Mayer, 2009; Karpicke & Blunt, 2011). The current study addressed these questions specifically with regard to

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whether the elaborative retrieval hypothesis can be applied to learning from complex scientific texts.

Elaborative retrieval and the testing effect

Some accounts of the testing effect focus on retrieval practice as the primary mechanism for enhanced retention (Roediger & Karpicke, 2006a). These accounts suggest that testing strengthens a memory trace by practicing the retrieval skills necessary for later retrieval. Karpicke and Blunt (2011) demonstrated that repeated free recall practice led to superior final test performance when compared to elaborative concept mapping and argued that retrieval likely reduces the number of cues used to retrieve an item from memory, rather than elaborating the connections between items. In this way, the power of retrieval is in strengthening the accessibility of individual memory traces, possibly by making those memory traces more distinctive (see also Karpicke & Smith, 2012).

In contrast, some researchers have suggested that retrieval practice can serve to elaborate the contents of mental representations (Carpenter, 2009; McDaniel & Masson, 1985) by encouraging the learner to re-organize or supplement initially encoded information. Carpenter (2009) proposed that one reason that retrieval benefits long-term memory over restudy is that retrieval is more likely to activate related elaborative information. This *elaborative retrieval hypothesis* is consistent with several pieces of data. Most convincingly, Carpenter (2011) demonstrated that cued-recall practice tests enhanced retention not only for target information (e.g. "child" in the pair "mother: child") but also enhanced retention for words with strong semantic associations with the pair (e.g. "father"). Enhanced retention of this "semantic mediator" suggests that retrieval attempts in this context served to broaden, rather than focus, the activation of information in semantic networks. The elaborative retrieval hypothesis is also consistent with data showing that more difficult retrieval attempts are more effective for long-term retention (Carpenter, 2009; Pyc & Rawson, 2010; see Bjork (1994) for a more general desirable difficulties framework). For instance, short answer tests are more demanding than multiple-choice tests, but are more effective for long-term retention (Butler & Roediger, 2007; McDaniel, Anderson, Derbish, & Morrisette, 2007). Similarly, more open-ended recall tests are more demanding and more effective than cued-recall tests (Glover, 1989; Hinze & Wiley, 2011). According to the elaborative retrieval account, more demanding retrieval attempts require the learner to actively reconstruct the content, and this reconstructive process necessitates the access of additional information that is then associated with the existing memory trace (Carpenter, 2011). This elaboration during retrieval is, at least in part, why those memory traces are more accessible at delayed tests.

Constructive retrieval and learning from texts

The goal of the present research is to consider what types elaborative processes during retrieval will enhance comprehension of complex text materials, with comprehension evidenced by enhanced transfer performance. (For our purposes, we define a "transfer" test broadly as any final test that differs from initial tests, either by testing the same materials in a different format, or by testing related but not identical information.) A few experiments on learning from text have demonstrated benefits of retrieval attempts, with feedback and/or restudy, on these sorts of transfer tests (Butler, 2010; Karpicke & Blunt, 2011; McDaniel, Howard, & Einstein, 2009). However, while more successful performance on transfer tests is thought to reflect better understanding of the text contents (Kintsch, 1994; Mayer, 2001; Wiley, Griffin, & Thiede, 2005), it is not clear what role, if any, *elaborative* retrieval played in obtaining these benefits (Karpicke & Blunt, 2011).

In order to apply the ideas of elaborative retrieval to complex learning situations, it helps to consider research and theory on text comprehension and learning from text. According to Kintsch (1994, 1998), learning from texts involves not only memory for words as presented (the surface form), but also the abstracted representation of propositions (the textbase) and a representation of the meaning of the text and its relationship to prior knowledge (the situation model). The situation model depends not only on the text itself, but on connections that are made between distal parts of the text and/or inferences based on prior knowledge. Because of this, building a coherent, enduring, representation of a text is a *constructive* process and is dependent on the generation of inferences during (or after) reading. Thus, to the extent that "elaboration" enhances long-term retention of textual materials, it may be through facilitation of these inferences with the aim of constructing a coherent representation of the text in memory.

This process of constructing coherent representations differs somewhat from the elaborative processes described in paired-associate learning (Carpenter, 2009, 2011). Consider the requirements of learning from science texts. While the types of associations elaborated in paired-associates learning may be facilitated through spreading activation, coherent situation model representations of science text content typically require a series of causal inferences to integrate pieces of information into an accurate mental model of the phenomena (Graesser, Leon, & Otero, 2002; Kintsch, 1994; Wiley et al., 2005). For example, readers of a text on cell mitosis need to not only remember the names of the phases (prophase, anaphase, etc.), but how one phase necessarily proceeds the previous step (and vice versa; see Millis & Graesser, 1994). Unfortunately, students with low prior knowledge, poor reading ability, or limited working memory capacity often have difficulty making these sorts of inferences while reading expository texts (e.g. McNamara, Kintsch, Songer, & Kintsch, 1996; Voss & Siflies, 1996; Wiley & Myers, 2003). Yet, measures of long-term learning tend to rely most heavily on situation-level representations, rather than rote memory of words or sentences (e.g. Kintsch, Welsch, Schmalhofer, & Zimny, 1990). Because of this, much research has focused on the conditions that may encourage the development of a coherent situation-model level representation, and more active or constructive processing during reading (Kintsch, 1998). It may be the case that these same sorts of *constructive* processes can be encouraged during retrieval practice, and may be in evidence