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When does retrieval induce forgetting and when does it induce facilitation? Implications for retrieval inhibition, testing effect, and text processing

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ABSTRACT

Retrieval practice can enhance long-term retention of the tested material (the testing effect), but it can also impair later recall of the nontested material – a phenomenon known as retrieval-induced forgetting (Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(5), 1063–1087). Recent research, however, has shown that retrieval practice can sometimes improve later recall of the nontested material – a phenomenon termed retrieval-induced facilitation (Chan, J. C. K., McDermott, K. B., & Roediger, H. L. (2006). Retrieval-induced facilitation: initially nontested material can benefit from prior testing of related material. *Journal of Experimental Psychology: General, 135*, 553–571). What drives these different effects? Two experiments were designed to examine the conditions under which retrieval induces forgetting and facilitation. Two variables, the level of integration invoked during encoding and the length of delay between retrieval practice and final test, were revealed as critical factors in determining whether testing facilitated or hindered later retrieval of the nontested information. A text processing framework is advanced to account for these findings.

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When does retrieval induce forgetting and when does it induce facilitation?

Although the idea of "frequent testing" may elicit negative reactions from students and educators alike, psychologists have long suspected that testing may have a positive influence on learning and its implications for education (Abbott, 1909; Ballard, 1913; Bjork, 1975; Brown, 1923; Gates, 1917; Naveh-Benjamin, 1990; Spitzer, 1939). In current scientific terms, this beneficial effect of retrieval is known as the *testing effect*. That is, taking an intervening test between learning and a delayed test boosts recall performance on that delayed test relative to a condition in which no initial test is taken (for reviews, see Crooks, 1988; Roediger & Karpicke, 2006).

During the earlier years of research on the testing effect, theorists suggested that the memorial benefits of testing are confined to materials that have been directly tested on the initial test (Duchastel, 1981; LaPorte & Voss, 1975; Nungester & Duchastel, 1982; Runquist, 1983; Runquist, 1986). Recent studies, however, have revealed that testing, or retrieval practice, also influences later memory of the nontested materials. These findings are important from an educational perspective because critics of the testing effect have argued that test-enhanced learning has limited pedagogical generality because rigid learning of discrete, factual knowledge differs significantly from learning in the real world (Daniel & Poole, 2009). However, such a criticism misses an important aspect of retrieval. That is, retrieval serves more than to simply reinforce memory of a tested fact. For example, the effectiveness of testing as a flexible learning tool has been demonstrated in multiple approaches, including the beneficial effects of initial test-

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ing on subsequent new learning (Chan, Thomas, & Bulevich, 2009; Izawa, 1970; Robbins & Irvin, 1976; Szpunar, McDermott, & Roediger, 2008; Tulving & Watkins, 1974), which is, in effect, a type of transfer in learning (Phye & Sanders, 1992). Indeed, the flexibility of retrieval is particularly apparent when its effects are demonstrated on the nontested materials. Therefore, a deeper understanding of the effects of retrieval on later memory of the nonretrieved items has important implications for educational practice.

Two literatures have independently investigated the later effects of testing on the nontested materials. Interestingly, they have arrived at different conclusions. For example, the conclusion from the *retrieval-induced forgetting* literature is that retrieval practice can impair later recall of the nontested materials (for reviews, Anderson, 2003; Bjork, Bjork, & MacLeod, 2006). In contrast, research from the *adjunct questions* tradition produced the opposite conclusion. Adjunct questions are questions embedded in the body of the text that students study. They can appear before (prequestions) or after the text (postquestions). Overall, research in this literature has found that answering adjunct questions facilitates later recall of the materials that are related to the adjunct questions (for reviews, see Crooks, 1988; Hamaker, 1986). The purpose of the current study is to elucidate variables that modulate the likelihood of obtaining facilitative vs. inhibitory effects of testing on the nontested materials. In the following sections, I first review the relevant literatures on retrieval-induced forgetting and retrieval-induced facilitation; I then present the logic behind the current experiments.

Evidence for retrieval-induced forgetting

In an influential paper, Anderson, Bjork, and Bjork (1994) investigated the following question: after studying a list of categorized words (e.g., Fruit: orange, apple, banana, etc.), will performing retrieval practice on a subset of the exemplar words (e.g., orange) affect later recall of the nontested exemplar words (e.g., banana)? Anderson and colleagues' experiment included four phases: a study phase, a retrieval practice phase, a distractor phase, and a final test phase. During the study phase, subjects studied category–exemplar pairs (e.g., fruit – orange, fruit – banana, drinks – scotch, drinks – rum, etc.). During the retrieval practice phase, subjects performed a cued recall test on half of the exemplars from half of the categories (e.g., they might be tested on fruit – or____ but not fruit – ba____, and not any items in the drinks category). After a distractor phase (which typically lasts 5–30 min), subjects' memory of the studied items is assessed on a final test. The practiced items are denoted Rp+, the nonpracticed items from the practiced category are denoted Rp−, and the items from the nonpracticed category are denoted Nrp. The general finding from this literature is that recall probability of the Rp− items is lower than that the Nrp items, which suggests that retrieval practice of the Rp+ items has impaired subsequent recall of their related (Rp−) items. Anderson and his colleagues termed this finding *retrieval-induced forgetting*.

Briefly, the theoretical framework for retrieval-induced forgetting states that during the retrieval practice phase, suppression of the Rp− items serves to enhance retrieval of the Rp+ items. Rp− items are suppressed because they are retrieval competitors against the Rp+ items. This suppression/inhibition is later manifested as a reduction in the recall probability of the Rp− items during the delayed, final test. To ensure that retrieval inhibition occurs on the item level (i.e., the representation of banana itself) rather than on the association level (i.e., the linkage between fruit and banana), Anderson and colleagues demonstrated that retrieval-induced forgetting occurred even when an extra-list (or independent) cue was used to probe the Rp− item (e.g., yellow – ba____). Notably, though, the magnitude of retrieval-induced forgetting is typically smaller (and sometimes absent) with independent probes than that with studied (or intra-list) cues (Camp, Pecher, & Schmidt, 2007; Camp, Pecher, Schmidt, & Zeelenberg, in press; Perfect et al., 2004; Williams & Zacks, 2001), which suggests that retrieval inhibition may occur on both the item and association level.

The retrieval-induced forgetting paradigm has generated a wealth of research. Indeed, retrieval-induced forgetting has been shown in a wide variety of tasks (for reviews, see Anderson, 2003; Anderson & Neely, 1996; Bjork et al., 2006; and for a recent report on the neural correlates of retrieval-induced forgetting, see Wimber, Rutschmann, Greenlee, & Bauml, 2008). Although agreement on the theoretical underpinnings of retrieval-induced forgetting has yet to be reached (e.g., Anderson & Spellman, 1995; Dodd, Castel, & Roberts, 2006; Norman, Newman, & Detre, 2007; Racsmany & Conway, 2006; Spitzer & Bauml, 2009; Williams & Zacks, 2001), the empirical conclusion from this literature is clear: retrieval practice can impair subsequent recall of the nontested-related material.

Evidence for retrieval-induced facilitation

Although the literature on retrieval-induced forgetting may lead one to caution the memorial benefits of testing, a few recent studies (Callender & McDaniel, 2007; Carpenter, Pashler, & Vul, 2007; Chan, McDermott, & Roediger, 2006), in addition to studies in the adjunct questions literature (Hamaker, 1986), have suggested that retrieval practice can sometimes enhance later recall of the nontested materials. For example, Carpenter et al. (2007) found that, in a paired associates learning task, retrieval practice of the target words enhanced subsequent recall of the cue words. That is, after learning word pairs such as "angle – corner" and performing retrieval practice (with corrective feedback) on "angle – ?", delayed (18–48 h later) recall of the cue word (angle) was enhanced relative to restudying the entire pair. Since exposure to the cue word was equated between the retrieval practice and restudy conditions, the enhanced recall of the cue can only be attributed to retrieval practice of the target. These researchers thus concluded that the testing benefit "spilled over to facilitate recall of information that was present on the test but was not retrieved". (p. 826, see also Kahana, 2002; Sommer, Schoell, & Buchel, 2008, for recent reviews of the vast literature on associative symmetry.)

More pertinent to the current purpose are results reported by Chan et al. (2006). In one experiment, subjects