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Differentiation of subsequent memory effects between retrieval practice and elaborative study

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ABSTRACT

Retrieval practice enhances memory retention more than re-studying. The underlying mechanisms of this retrieval practice effect have remained widely unclear. According to the elaborative retrieval hypothesis, activation of elaborative information occurs to a larger extent during testing than re-studying. In contrast, the episodic context account has suggested that recollecting prior episodic information (especially the temporal context) contributes to memory retention. To adjudicate the distinction between these two accounts, the present study used the classical retrieval practice effect paradigm to compare retrieval practice and elaborative study. In an initial behavioral experiment, retrieval practice produced greater retention than elaboration and re-studying in a one-week delayed test. In a subsequent event-related potential (ERP) experiment, retrieval practice resulted in reliably superior accuracy in the delayed test compared to elaborative study. In the ERPs, a frontally distributed subsequent memory effect (SME), starting at 300 ms, occurred in the elaborative study condition, but not in the retrieval practice condition. A parietal SME emerged in the retrieval practice condition from 500 to 700 ms, but was absent in the elaborative study condition. After 700 ms, a late SME was present in the retrieval practice condition, but not in the elaborative study condition. Moreover, SMEs lasted longer in retrieval practice than in elaboration. The frontal SME in the elaborative study condition might be related to semantic processing or working memory-based elaboration, whereas the parietal and widespread SME in the retrieval practice condition might be associated with episodic recollection processes. These findings contradict the elaborative retrieval theory, and suggest that contextual recollection rather than activation of semantic information contributes to the retrieval practice effect, supporting the episodic context account.

1. Introduction

Previous research has shown that retrieval practice improves subsequent memory performance more than re-studying does (Roediger & Butler, 2011; Karpicke & Roediger, 2008). This phenomenon has been labeled the retrieval practice effect, and it has been repeatedly demonstrated using various laboratory and practical educational materials (e.g., Karpicke & Blunt, 2011; Carpenter, 2009; Lehman et al., 2014). However, the cognitive mechanism underlying the retrieval practice effect is still a matter of debate.

Carpenter (2009) proposed the elaborative retrieval hypothesis to explain the mechanisms underlying the retrieval practice effect. The core concept of this account is that retrieval practice activates more semantic information (words or concepts) related to the recalled targets than re-studying does (Carpenter & DeLosh, 2006; Carpenter, 2009, 2011). For example, in one study, Carpenter (2009) manipulated the strength of the cue-target relationship. Participants studied weakly related pairs (e.g., Basket: Bread) and strongly related pairs (e.g., Toast: Bread). Subsequently, they performed either a cued-recall task or a re-studying task. Five minutes later, they needed to recall all of the targets they could remember. The findings showed that weakly related cue-target pairs were retained better than strongly associated pairs for the retrieval practice condition in the final free recall task. However, the cue-to-target strength did not affect memory retention for previously restudied items. The author argued that for the weakly associated pairs, more information semantically related to the cues was generated and elaborated by retrieval practice than by re-studying. This mediating information was spontaneously activated in the later test and increased

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the likelihood of successful retrieval for targets (Carpenter, 2009).

However, much of the evidence supporting the elaborative retrieval hypothesis is indirect, based on inferences from behavioral measures (such as response times and accuracy), and did not stem from direct investigations of the underlying cognitive processes. Thus, these experimental results are correlational rather than explanatory evidence for the elaborative retrieval hypothesis (Lehman et al., 2014; Karpicke, Lehman, & Aue, 2014). Furthermore, the elaborative retrieval hypothesis violates the cue-overload principle, which states that additional retrieval cues decrease the efficiency of retrieval (Watkins & Watkins, 1976). The hypothesis also has difficulties in explaining retrieval practice effects beyond those of semantic words, such as visuospatial maps (Carpenter & Pashler, 2007; Kang, 2010).

Karpicke et al. (2014) argued that if the hypothesis that participants form an elaborative network with some activated semantic concepts during retrieval was reasonable, elaboration should produce mnemonic effects similar to those produced by retrieval practice. Karpicke and Blunt (2011) compared the impact of retrieval practice and of concept mapping (as an elaborative study condition) on memory retention in a test one week later. They found that participants in the retrieval practice group performed better in the final test than participants who participated in the concept mapping task, tentatively suggesting that the mechanisms behind the retrieval practice effect were different from the cognitive processes of elaboration. In addition, Karpicke and Smith (2012) observed consistent results when using other kinds of elaborative study strategies, such as an imagery-based keyword method.

Based on these experimental results, Karpicke et al. (2014) argued that activating semantically related information was not crucial for the retrieval practice effect. They put forth a new account for the retrieval practice effect, the episodic context account, which suggests that during active retrieval participants recall and reconstruct prior study episodes, particularly their temporal context. During active retrieval, participants update the episodic representation with reinstated temporal context information. This information can be used as a retrieval cue, making the target more retrievable in later memory tests. This account suggests that the amount of recalled detailed information adjusts the memory enhancement.

Nonetheless, Karpicke and colleagues' investigations of the effects of retrieval practice and elaborative study on memory performance were based on behavioral experiments, thus they could only infer the potential mechanisms behind the retrieval practice effect (Lehman et al., 2014). Therefore, whether elaborative processing or context reinstatement is the underlying mechanism of the retrieval practice effect still awaits more evidence. Only a few functional neuroimaging studies have aimed to reveal the neurocognitive processes underlying the retrieval practice effect (Eriksson, Kalpouzos, & Nyberg, 2011; Hashimoto, Usui, Taira, & Kojima, 2011; Keresztes, Kaiser, Kovács, & Racsmány, 2014; van den Broek, Takashima, Segers, Fernández, & Verhoeven, 2013; Wing, Marsh, & Cabeza, 2013). For example, Wing et al. (2013) investigated subsequent memory effects (SMEs) in order to identify brain areas relevant for the retrieval practice effect. SMEs are differences in neural activity triggered by subsequently remembered items and by subsequently forgotten items. Wing et al. observed larger SMEs in the bilateral hippocampus, lateral temporal cortex and medial prefrontal cortex for the retrieval practice condition than for the re-studying condition. The increased activity in the hippocampus might be related to the reinstatement of previously formed associations, as well as the updating of representations via integration of disparate information. However, this study focused on comparing encoding processes during retrieval practice and re-studying without considering elaboration, so the authors were not able to differentiate between the elaborative retrieval hypothesis and the episodic context account.

Researchers using the event-related potential (ERP) technique, which possesses high temporal resolution, have consistently shown that episodic recollection and the quantity of retrieved information are both indexed by the late parietal component (LPC) at 500–800 ms latency (Vilberg, Moosavi, & Rugg, 2006; Friedman & Johnson, 2000; Mecklinger, 2006; Rugg & Curran, 2007). Recently, some researchers used the ERP method to examine the neural correlates of the retrieval practice effect (Rosburg, Johansson, Weigl, & Mecklinger, 2015; Gao et al., 2016). For instance, Rosburg et al. (2015) analyzed the electrophysiological consequences of active retrieval by comparing old/new effects of previously tested items and untested items in a source memory task. The results suggested that the left parietal old/new effect was significantly superior for previously tested items than for previously untested items (Rosburg et al., 2015). However, the study only compared ERP differences induced by tested and untested items, as opposed to differentiating neural activity between retrieval practice and elaborative study. In addition, the difference in exposure time between tested and untested items may have been a confounding factor in this study. Moreover, the authors examined the outcome of retrieval practice rather than the neural activity occurring at the time of active retrieval. In contrast, Bai, Bridger, Zimmer, and Mecklinger (2015) used a subsequent memory paradigm to elucidate ERP correlates of retrieval practice occurring at initial test. They observed that the scalp topography of the 500–700 ms SME for tested pairs resembled the parietal old/new effect. The findings of these two ERP studies indicated that retrieval-specific processes, such as detailed context recollection, might benefit the retrieval practice effect, and were consistent with the episodic context account.

To our knowledge, neurophysiological studies have so far never aimed to compare the elaborative retrieval hypothesis and the episodic context account. Thus, whether the underlying mechanism of the retrieval practice effect is semantic elaboration or recollection of episodic context remains unclear. In the present study, Experiment 1 compared the behavioral mnemonic effects of retrieval practice, elaborative study, and re-studying. Experiment 2 investigated the neural correlates of successful encoding for retrieval practice and elaborative study. This experiment explored SMEs at retrieval practice and elaborative study within a classical retrieval practice effect paradigm (comprising study phase, initial retrieval phase, and final test phase), see Fig. 1. During the study phase, participants memorized weakly related word pairs (such as Experiment-Chemical; Theory-Hypothesis; Grammar-Book). These items were then assigned to one of the initial retrieval conditions: re-studying (only in Experiment 1), elaborative study (participants had to generate semantic mediators to relate cues and targets), or retrieval practice (cued-recall task). One week later, participants completed a recognition test and had to identify presented word pairs as "old" (studied pairs, such as Grammar-Book), "recombined" (rearranged pairs, such as Experiment-Hypothesis), or "new" (unstudied pairs). Old, recombined, and new word pairs were all semantically weakly related in order to avoid reliance on semantic relationship strength when judging the items.

Our hypotheses were as follows: For Experiment 1, retrieval practice would outperform elaborative study and re-studying in the delayed test, even when restricting retrieval practice to a single test (Roediger & Butler, 2011; Rowland, 2014). For Experiment 2, retrieval practice and elaborative study would differ behaviorally and in their ERP correlates. Specifically, the subsequent memory performance of retrieval practice would be superior to that of elaborative study. For ERPs, spatiotemporally distinct SMEs would occur for retrieval practice and elaborative study. In the retrieval practice condition, SMEs would resemble the LPC, as reported by Bai et al., 2015. Superior memory performance and distinct SMEs for the retrieval practice condition in comparison to the elaborative study condition would both be considered counterevidence for the elaborative retrieval hypothesis.