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Practicing more retrieval routes leads to greater memory retention

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ABSTRACT

A wealth of research has shown that retrieval practice plays a significant role in improving memory retention. The current study focused on one simple yet rarely examined question: would repeated retrieval using two different retrieval routes or using the same retrieval route twice lead to greater long-term memory retention? Participants elaborately learned 22 Japanese-Chinese translation word pairs using two different mediators. Half an hour after the initial study phase, the participants completed two retrieval sessions using either one mediator ($T_{m1}T_{m1}$) or two different mediators ($T_{m1}T_{m2}$). On the final test, which was performed 1 week after the retrieval practice phase, the participants received only the cue with a request to report the mediator (M1 or M2) followed by the target (Experiment 1) or only the mediator (M1 or M2) with a request to report the target (Experiment 2). The results of Experiment 1 indicated that the participants who practiced under the $T_{m1}T_{m2}$ condition exhibited greater target retention than those who practiced under the $T_{m1}T_{m1}$ condition. This difference in performance was due to the significant disadvantage in mediator retrieval and decoding of the unpracticed mediator under the $T_{m1}T_{m1}$ condition. Although mediators were provided to participants on the final test in Experiment 2, decoding of the unpracticed mediators remained less effective than decoding of the practiced mediators. We conclude that practicing multiple retrieval routes leads to greater memory retention than focusing on a single retrieval route. Thus, increasing retrieval variability during repeated retrieval practice indeed significantly improves long-term retention in a delay test.

1. Introduction

A great deal of research suggests that retrieval practice not only serves to assess what was learned but also plays a significant role in promoting learning and memory (Abott, 1909; Karpicke & Roediger, 2008; Roediger & Karpicke, 2006; for a review, see Roediger & Butler, 2011). Researchers have performed many experiments to establish the most effective modes of retrieval practice, including the ideal intervals (Karpicke & Roediger, 2007; Landauer & Bjork, 1978) and criterion (Rawson & Dunlosky, 2011) of repeated retrieval, the amount of elaboration (Carpenter, 2009; Carpenter & DeLosh, 2006), and the recollection of the initial episodic context (Karpicke, Lehman, & Gallo, 2014; Karpicke & Zaromb, 2010) during the retrieval phase. Surprisingly, few studies have explored one simple but rather important question: whether consolidating multiple retrieval routes or consolidating one retrieval route multiple times would achieve greater memory retention? In the current study, two experiments were performed to examine which mode of retrieval is more beneficial to memory retention: retrieval practice using two different mediators or using the same mediator twice?

Although there has been a lack of research directly comparing the effectiveness of repeated retrieval using multiple retrieval routes with that using a single retrieval route multiple times, prior research focused on encoding variability (e.g. Gartman & Johnson, 1972; Glanzer & Duarte, 1971; Greenberg & Verfaellie, 2010; Smith, Glenberg, & Bjork, 1978), retrieval variability (e.g., Finley, 2012) and retrieval-based learning (e.g. Carpenter, 2009; Lehman, Smith, & Karpicke, 2014) has provided some indirect evidence related to this issue. Prior studies have demonstrated the benefit of encoding variability at the semantic level (Glanzer & Duarte, 1971; Greenberg & Verfaellie, 2010; Hintzman & Stern, 1978) and the physical/context level (Smith et al., 1978) during the initial study phase. For example, in an experiment by Greenberg and Verfaellie (2010), healthy elderly people studied word pairs three times either under a fixed condition (the mediator remained constant with each presentation, e.g., ARMY invades CITY) or under a varied condition (the mediator changed with each presentation, e.g., ARMY invades CITY, ARMY flees CITY, or ARMY patrols CITY). The participants who studied under the varied condition performed better on a

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subsequent associative-recognition task than those who studied under the fixed condition. Similarly, Smith et al. (1978, Experiment 1) assigned the participants to study the to-be-remembered list either twice in exactly the same room or once each in two very different rooms. Then, all participants underwent a surprise free recall test in a neutral room. The superior performance of the group that studied in different rooms was consistent with the concept of mnemonic benefit for encoding variability. To our knowledge, Finley (2012) was the first to consider the issue of retrieval variability during the retrieval practice phase. In Finley's experiment, English homographic target words were presented together with four associated cue words (two cues for each of the two meanings) during the initial study phase. For example, one target word was "bat", and its four cue words were "swing, hit, fangs, and cave". Five minutes later, the participants were shown two cue words for each target word to complete the cued recall test. Double-meaning retrieval cues (e.g., swing and fangs) indeed yielded higher recall than single-meaning retrieval cues (e.g., swing and hit) (Experiment 3). This result demonstrated that increasing the variability of retrieval cues indeed greatly improves the present retrieval performance. Based on these results, would increasing the variability of repeated retrieval significantly improve long-term retention on a delay test? On the basis of the literature related to encoding variability and retrieval variability, repeated retrieval using two different retrieval routes is more likely to construct retrieval variability than repeated retrieval using the same retrieval route twice. Thus, we inferred that repeated retrieval using two different retrieval routes would be more effective than repeated retrieval using the same retrieval route twice, but this hypothesis required the support of direct evidence.

Recently, based on the accounts of spacing effects according to the contextual variability and study-phase retrieval theories, Karpicke and colleagues proposed an episodic context account of retrieval-based learning (Karpicke, Lehman, & Aue, 2014; Lehman et al., 2014), which emphasizes the roles of context reinstatement and updating during successful retrieval in increasing the retention of retrieved information. The context representation of successfully retrieved items may be updated into a composite of temporal contextual features during the initial study and retrieval practice phases. When participants subsequently attempt to retrieve the items, they can restrict their search to those items which are associated with the updated context (Karpicke, Lehman & Aue, 2014). However, the effect of contextual variability evoked by retrieval variability during the repeated retrieval practice phase on memory performance has not been explored. According to the episodic context account of retrieval-based learning, we inferred that repeated retrieval using two different retrieval routes would increase contextual variability in encoded traces and that the combination of retrieval routes would be more unique and specific to the target. Because the difference in memory retention between distinct modes of repeated retrieval was not directly examined in prior studies, it is necessary to directly compare these two retrieval conditions to gain a deeper understanding of the episodic context account.

Additionally, Bjork (1975) proposed that the concept of retrieval routes is also a concept of elaboration. In accordance with this proposal, we consider that two properties define the degree of "elaboration": the number of mediators (cascade form) included in one retrieval route and the number of retrieval routes provided by the mediators (parallel form). Multiple studies by Carpenter and colleagues have explored elaborative retrieval as a retrieval route that is encoded by highly relevant information (e.g. Carpenter, 2009; Carpenter & DeLosh, 2006). Carpenter (2009) stated that when people attempt to retrieve a target from memory, they activate several semantically related words while searching for the target and that this semantic elaboration during initial retrieval enhances retention on future tests (Carpenter, 2009, 2011). For example, after initial study of a word pair (e.g., Basket: Bread), recalling a target from a cue (e.g., Basket: ____) is more likely to activate elaborative information that is related to the cue (e.g., Eggs or Wicker). However, the effect of manipulating semantic elaboration by changing the number of retrieval routes provided by the mediators has rarely been examined. The present study was performed to resolve this deficiency.

The current study directly examined whether retrieval practice using two different mediators or the same mediator twice would achieve greater memory retention. As depicted in Fig. 1, the paradigm in the current experiments was modelled after the report by Pyc and Rawson (2010). Both experiments included three phases: an initial study phase, a retrieval practice phase, and a final test phase. The initial study and retrieval practice phases were identical between the two experiments. In the initial study phase, participants were instructed to utilize mediators to study a list of Japanese-Chinese translation pairs. They completed two initial study sessions (S1 & S2, see Fig. 1), each involving one mediator for each pair. To better control the establishment of the retrieval route, mediators were assigned by the experimenter instead of the participants. Thus, two mediators were introduced to ensure that all participants would be provided an opportunity to establish two retrieval routes for each word pair. After the initial study phase, the participants completed two retrieval practice sessions (T1 & T2, see Fig. 1), either using the same mediator ($T_{m1}T_{m1}$ condition) or different mediators ($T_{m1}T_{m2}$ condition). Under the $T_{m1}T_{m1}$ condition, each participant was provided with two opportunities to consolidate the retrieval route for one mediator but no opportunities for the other mediator. Under the $T_{m1}T_{m2}$ condition, each participant was provided with one opportunity to consolidate the retrieval route for each of the two mediators. In Experiment 1, a final cued recall test, which involved cue recall and mediator recall (CMR test), was adopted to explore the differences in performance of target recall, mediator retrieval (i.e., the mediator is recalled when prompted with the cue) and mediator decoding (i.e., the mediator elicits the target from memory) between the two retrieval practice conditions. In Experiment 2, a final test using only one mediator (M test) was adopted to further explore mediator decoding.

2. Experiment 1

In Experiment 1, after the initial study phase, participants were randomly assigned to two groups, the $T_{m1}T_{m1}$ condition or the $T_{m1}T_{m2}$ condition. Under the $T_{m1}T_{m1}$ condition, only one mediator was used during the two sessions of retrieval practice. Under the $T_{m1}T_{m2}$ condition, two mediators were used during the two sessions of retrieval practice. All participants received the final cued test to recall the mediator and the target (see Fig. 1). We assessed whether consolidating more retrieval routes would lead to greater memory retention. When the target was successfully retrieved twice during the retrieval practice phase, this item was considered to have been successfully retrieved either twice via a single retrieval route ($T_{m1}T_{m1}$ condition) or once each via two different retrieval routes ($T_{m1}T_{m2}$ condition). Thus, how items which were successfully retrieved twice during the retrieval practice phase retained on the final test was the primary focus of the current study. We hypothesized that target retention under the $T_{m1}T_{m2}$ condition would be greater than that under the $T_{m1}T_{m1}$ condition one week after retrieval practice phase. To further explain the mechanism underlying this hypothesized difference in target retention, we specifically analysed mediator retrieval and mediator decoding performance.

2.1. Method

2.1.1. Participants

Sixty-four students (30 males, 34 females) from Beijing Normal University participated in Experiment 1 for a reward. Thirty participants (16 females; mean age = 22.37; SD = 2.08) practiced under the $T_{m1}T_{m1}$ condition, and thirty-four participants (18 females; mean age = 21.59; SD = 2.46) practiced under the $T_{m1}T_{m2}$ condition. All participants had normal or corrected vision, were native speakers of Chinese, and had no previous experience with Japanese. The participants completed the experiment in individual booths on desktop PCs.