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Effects of incorporating retrieval into learning tasks: The complexity of the tasks matters

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ABSTRACT

In an experiment with $N = 192$ university students, we examined whether the effects of incorporating retrieval into learning tasks depend on the learning tasks' complexity. The learning tasks consisted of adjunct questions that were provided together with expository texts relating to the domain of chemistry. We varied (a) whether the adjunct questions required the learners to summarize (low complexity) or generate inferences on the basis of provided information (high complexity) and (b) whether the adjunct questions were implemented in a closed-book style that required learners to engage in retrieval or in an open-book style that did not require learners to engage in retrieval while responding to the questions. Afterwards, all learners took either an immediate or a delayed criterion test. We found that the effect of incorporating retrieval depended on the complexity of the adjunct questions; the net benefit of incorporating retrieval was higher for the low complexity ones.

1. Introduction

Retrieving information from memory can strengthen one's memory of the retrieved information. This core finding of research on *retrieval-based learning* (e.g., Roediger & Butler, 2011; Rowland, 2014) recently gave rise to the claim that incorporating retrieval into tasks that are designed to engage learners in knowledge construction activities (in the following referred to as *learning tasks*) is a powerful way to enhance their effectiveness (Blunt & Karpicke, 2014; Karpicke & Grimaldi, 2012). That is, learning tasks (e.g., the task of constructing a concept map or responding to questions) should be more effective when they are implemented in a *closed-book style* in which learners cannot reinspect the learning material (e.g., an expository text) and thus have to engage in retrieval while performing the respective task than an *open-book style* in which the learning material is still available while learners perform the tasks.

In this article, we make the case that incorporating retrieval into learning tasks does not simply exploit an often overseen potential but actually has double-edged effects: On the one hand, it encourages learners to engage in retrieval, which beneficially affects learning outcomes via decreased forgetting rates. However, because learners rarely recall all content items of the learning material perfectly (e.g., Rowland, 2014), it on the other hand decreases the amount of successfully executed knowledge construction activities at which the respective learning tasks are targeted and thus detrimentally affects learning outcomes. Furthermore, we argue that the extent of this detrimental effect depends on the degree to which learning tasks require learners to combine content items that are included in the learning material (hereafter referred to as *complexity* of learning tasks). When the degree of complexity increases, the detrimental effect should increase as well.

Jointly, these considerations yield the prediction that the net benefit of incorporating retrieval into learning tasks should decrease as learning tasks become more complex. We investigated this hypothesis in a setting in which learners received expository texts as the type of learning material and low or high complexity *adjunct questions* as the type of learning task. Adjunct questions are questions that are added to an expository text in order to influence learners' knowledge construction activities regarding the text's content (Hamaker, 1986; see also; Andre, 1979; Cerdán, Vidal-Abarca, Martínez, Gilabert, & Gil, 2009; McCrudden & Schraw, 2007; Roelle, Berthold, & Renkl, 2014). For instance, concerning an expository text that is designed to introduce learners to atomic structure, adjunct questions might include the following examples: "Summarize the composition of the atomic shell" or "Explain the extent to which lithium and carbon differ in terms of their electrons and electron shells."

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1.1. The benefit of incorporating retrieval into learning tasks

Research on the retrieval-based learning approach indicates that the act of retrieval from memory (often referred to as *retrieval practice*) is a powerful way to promote learning (e.g., Blunt & Karpicke, 2014; Karpicke & Grimaldi, 2012; Lechuga, Ortega-Tudela, & Gómez-Ariza, 2015; Roediger & Butler, 2011; Roediger & Karpicke, 2006; Rowland, 2014). It shows that even when learning time is controlled for, learners who retrieve specific content items from memory experience lower forgetting rates than learners who do not.

The most comprehensive and cohesive theoretical explanation of the benefits of retrieval-based learning is the *episodic context account* (for an extensive description as well as evaluations of other accounts such as elaborative retrieval, transfer-appropriate processing, or encoding variability, see Karpicke, Lehman, & Aue, 2014). This account suggests that the successful retrieval of content items from memory fosters the future retrieval via two mechanisms. First, it updates the context representation that is stored with the respective items. That is, in order to retrieve content items, learners reinstate the context in which the items were encoded. When the retrieval is successful, features from the current (retrieval) context are added to the context representation of the retrieved items. On future retrieval occasions (e.g., during a criterion test), not only features of the encoding context but also these added features of the retrieval context can be used as cues to access the content items stored in memory. Hence, through context updating the number of effective retrieval cues increases. Second, successful retrieval entails the benefit that learners practice reinstating a specific context (e.g., the encoding context), which can facilitate future context reinstatement (e.g., during a criterion test; see Masicampo & Sahakyan, 2014).

Both context updating and practicing context reinstatement make retrieved content items more recallable in the future and thus yield decreased forgetting rates (Karpicke et al., 2014). The problem is, however, that learners scarcely engage in retrieval while performing learning tasks when it is not obligatory. For instance, a study by Blunt and Karpicke (2014) showed that when university students constructed a concept map while the learning material (here: an expository text) was available to them (i.e., the task of constructing a concept map was implemented in an *open-book style*), they insufficiently engaged in retrieval of the content items that were included in the expository text. In another study, Karpicke, Butler, and Roediger (2009) found that relatively few college students engage in retrieval while studying on their own (cf. Dunlosky & Rawson, 2015).

In view of the benefits of engaging in retrieval, these findings lead to the prediction that implementing learning tasks in a *closed-book style* in which learners cannot reinspect the learning material is a promising means to enhance their effectiveness (see Karpicke & Grimaldi, 2012). That way, retrieval is inevitably incorporated into learning tasks. Consequently, in comparison to an open-book implementation of learning tasks in which retrieval is not obligatory, a closed-book implementation should foster context updating and context reinstatement and thus result in decreased forgetting rates of the content items that are involved in the respective task. With respect to adjunct questions that are designed to foster the processing of expository texts (i.e., the learning tasks that are used in the present study), this implies that a closed-book implementation should decrease the forgetting rates of the content items that are needed to respond to the respective adjunct questions. In comparison to an open-book implementation of the same adjunct questions, this decrease in forgetting rates should contribute to an increase in performance on a criterion test.

Admittedly, the literature on retrieval-based learning includes findings that, at least at first glance, do not support this prediction. First, a series of recent studies gave rise to the (forgotten) claim that the benefit of incorporating retrieval into learning tasks decreases when the learning material becomes more complex (De Jonge, Tabbers, & Rikers, 2015; Leahy, Hanham, & Sweller, 2015; Van Gog et al., 2015; see also; Van Gog & Sweller, 2015). More specifically, these studies found that when the learning material was highly complex, learning tasks that required learners to engage in retrieval (e.g., problem-solving tasks) were not significantly superior to learning tasks that required learners to restudy the learning material (e.g., studying worked examples) in terms of learning outcomes. Jointly, these studies provide a solid basis for the fruitful conclusion that retrieval practice learning tasks are not necessarily more beneficial than restudy learning tasks. However, in terms of the question as to whether *incorporating retrieval into learning tasks* enhances the learning tasks' effectiveness, these studies should be interpreted cautiously because the retrieval and restudy conditions were different not only with regards to the amount of required retrieval but also to the learning task type. For instance, problem-solving or fill-in-the-blanks tasks (i.e., retrieval practice tasks) were compared to the tasks of (re)studying worked examples or rereading sentences (i.e., restudying tasks), respectively. Arguably, these learning tasks elicit different types of knowledge construction activities (e.g., problem-solving vs. self-explaining worked examples; see Renkl, 2014). Due to this confounding, the lack of effects found in these studies cannot simply be attributed to the notion that engaging in retrieval yields little to no benefit; the different knowledge construction activities that were elicited by the retrieval and restudy learning tasks could have contributed to the pattern of results as well (see Van Gog & Sweller, 2015). Furthermore, in his meta-analysis Rowland (2014) found beneficial effects of engaging in retrieval for both more complex (i.e., prose) and less complex (i.e., paired associates and word lists) text-based material (see also Rawson, 2015). Thus, based on the present literature, it does not seem warranted to expect that the benefit of incorporating retrieval into learning tasks that are designed to foster learning from text-based material (such as adjunct questions) would be restricted to less complex learning material.

Second, studies on retrieval-based learning indicate that the time of criterion test matters for the benefit of having engaged in retrieval. Although the beneficial effects of retrieval practice have been found on both immediate and delayed criterion tests (e.g., Karpicke et al., 2014; Smith, Roediger, & Karpicke, 2013), the literature clearly shows that the advantage of having engaged in retrieval is higher in the latter case (see Rowland, 2014). This pattern of results fits in nicely with the theoretical notion that engaging in retrieval decreases the forgetting rates of the retrieved content items. In light of these findings, rather than predicting a general advantage of a closed-book implementation style of learning tasks in comparison to an open-book implementation style, it seems more reasonable to predict an interaction between implementation style and time of criterion test such that the benefit of a closed-book implementation style is more pronounced on delayed than immediate criterion tests.

Although scarcely discussed in the literature on retrieval-based learning, a third potential qualification of the prediction that a closed-book implementation generally fosters the net effectiveness of learning tasks refers to the effects of implementation style on the extent to which learners successfully master the respective tasks. A tacit assumption of this prediction is that a closed-book style of task implementation *does not* reduce the number of successfully executed knowledge construction activities in response to the respective tasks. It is certainly questionable whether this assumption is met in each and every case.