Retrieving to remember: in theory and practice

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ABSTRACT

How can we best help students to remember? Psychology has revealed several ways in which educators can increase the chances of students remembering educational material in the long term. One such technique is retrieval practice. Students who practice retrieving educational material once learnt perform better on later tests than students who do not practice retrieving. This 'retrieval practice effect' or 'testing effect' is well established, having been shown in both the laboratory and classroom for a variety of learning materials. This paper presents the key findings and theoretical explanations of the retrieval practice effect, focussing on real-world pedagogical value. The paper also outlines how retrieval practice can be embedded in real-world educational environments that are typically encountered in higher education: the lecture theatre and the seminar room. The retrieval practice effect is a highly resilient, versatile tool that encourages long-term retention of educationally relevant material in students of all ages, and can be easily embedded in any manner of educational environment.

INTRODUCTION

A key aim in education is to promote the retention and utilisation of learnt knowledge in the long-term. We want students to be able to recall and use what they have learnt, not just following a seminar or lecture but throughout their life. More practically, we want students to recall information when completing assessments, which can often occur weeks or months after initial learning. This gap between initial learning and testing can be problematic, as forgetting rates for newly learnt material are often very rapid, occurring over the course of hours to days (an effect which has been noted for quite some time; see, foundationally, Ebbinghaus, 1885). The critical question therefore is how can we promote long-term retention of educational material: put simply, how do we get new information to stick?

Psychology has studied learning and memory systematically for over a century (since the seminal work of Ebbinghaus), and has made great progress theoretically (for reviews, see Bird & Burgess, 2008; Eichenbaum *et al.*, 2007; Horner & Doeller, 2017; Lambon Ralph *et al.*, 2016). Importantly, the field has also provided several practical strategies for effective learning (as noted in Dunlosky *et al.*, 2013; Putnam & Roediger, 2018; Weinstein *et al.*, 2018). One example is 'retrieval practice': the finding that final test performance can be improved through repeated prior retrieval (Roediger *et al.*, 2011). Imagine that you read a prose passage one week, and try to recall it the following week. If you actively try to retrieve the passage soon after your initial reading, you will recall more information the following week than if you had not engaged in active retrieval. Once new material has been learnt, repeated retrieval improves retention compared to no retrieval (Glover, 1989) and even repeated re-exposure (Roediger & Karpicke, 2006). It is better to practice retrieval than to re-study the same material.

The retrieval practice effect has been shown across a range of educational material (eg, Carpenter & Pashler, 2007; Karpicke, 2009; Roediger & Karpicke, 2006) in both laboratory settings (Roediger & Karpicke, 2006) and real-world educational environments (Leeming,

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2002), and shows improvements across a range of tests (eg, multiple choice and open-ended questions; Carpenter & DeLosh, 2006). Improved retention has even been shown to persist up to five years after initial learning (Bahrick *et al*., 1993). Finally, it can easily be embedded in a formal teaching environment with little cost in terms of time or money (Roediger *et al*., 2011). As such, it represents an effective and easily implementable learning strategy that has clear benefits in terms of long-term retention and test performance. Here I present the key empirical findings related to retrieval practice, focussing on the real-world pedagogical value of the strategy. I discuss the proposed theoretical explanations of the effect before outlining how retrieval practice can be practically embedded in typical settings in higher education: the lecture theatre and seminar room. This final section acts as a useful guide for educators interested in using the technique in their own educational practice.

DOES RETRIEVAL PRACTICE WORK?

Although the benefits of retrieval practice have long been known (Gates, 1917), systematic study of the effect was catalysed by the clear demonstration that retrieval practice worked with educationally relevant material (Roediger & Karpicke, 2006). Prior to this, much of the literature was concerned with improvements in the retention of arbitrary word lists (eg Hogan & Kintsch, 1971) or picture lists (eg Wheeler & Roediger, 1992). Roediger & Karpicke (2006) presented participants with prose passages, one related to the sun and the other to sea otters. One of the prose passages was assigned to the 'study' condition, where participants re-read the passage a second time following initial learning. The other passage was assigned to the 'test' condition, where participants were presented with the title of the passage (eg 'sea otters') and asked to write down as much information as they could remember from initial learning. Both passages were then tested after a delay (5 minutes, 2 days, or 1 week), and memory performance was compared between the 'study' and 'test' condition.

When tested after 2 days or 1 week, participants remembered significantly more information for the 'test' than the 'study' passage (the effect was not seen at 5 minutes, a finding I revisit below in 'when doesn't retrieval practice work?'). Indeed, after a week, there was a difference in performance between the two conditions of ~18%. Whereas performance in the 'study' condition was ~40% after a week, performance in the 'test' condition was ~58%. Roediger & Karpicke went on to show that repeated retrieval practice was more beneficial relative to repeated study. Thus, retrieval practice improves long-term (but not short-term) retention of educationally relevant material in a laboratory setting.

Importantly, the effect is not limited to retention of information presented in prose passages. Retrieval practice has been shown to work for retention of spatial maps (Carpenter & Pashler, 2007), learning of new language vocabulary (Karpicke, 2009), (fictional) general knowledge (Kornell *et al*., 2009), statistical knowledge (Zaromb & Roediger, 2010), and names of flower parts from a labelled drawing (Glover, 1989). Although there is an ongoing debate concerning whether the effect diminishes (or even disappears) as the complexity of the learnt material increases (van Gog & Sweller, 2015; but see also Karpicke & Aue, 2015), there is now a body of evidence suggesting retrieval practice improves long-term retention for a variety of educational material.

Another critical factor is that the effect can be seen across a range of testing conditions, from multiple-choice to more open-ended questions (Foos & Fisher, 1988). Further, the benefits are not dependent upon retrieval practice being undertaken in the same format as the final test. Carpenter & DeLosh (2006) presented participants with a prose passage and three different retrieval practice conditions: free recall, cued recall and recognition. The final test involved one of the three retrieval practice conditions such that, across participants, all nine combinations of retrieval practice and final test were assessed. First, relative to the control condition where no retrieval or further study took place, all retrieval practice

conditions showed improved retention. Thus, the effect is robust to the exact combination of test format during retrieval practice and final test. Second, free recall during retrieval practice produced the largest effect, irrespective of final test format. When participants are asked to retrieve as much information as possible on a given subject with few "cues" to guide retrieval, then long-term retention is improved relative to when retrieval is more restricted and guided by retrieval cues.

Laboratory-based studies of young adults (typically students at university) have shown the consistent benefits of retrieval practice, irrespective of material learnt and test format. Similarly sized effects have also been shown in children (Rohrer *et al.*, 2010) and older adults (Logan & Balota, 2008). The critical practical question is whether these effects have been shown to work in real-world educational environments. First, Leeming (2002) embedded a short (10-15 min) test at the beginning of every lecture for modules on 'learning and memory' and 'introductory psychology' delivered at the University of Memphis, Tennessee. The tests consisted of both short-answer and short-essay questions related to the material learnt in the previous lecture. Final grades in the modules were compared to the previous year's grades, where fewer tests were embedded during lectures. The average improvement in final grade was ~7%, suggesting that regular testing produces higher marks in real-world taught modules at university. Although caution is needed due to the comparison across two separate year groups, the increase of 7% is substantial and supported by more recent studies.

Lyle & Crawford (2011) had students enrolled in their introductory statistics course perform 2-6 questions at the end of each lecture. The content of the questions related to the content of the just completed lecture. The questions were targeted, with a single or two word correct answer to a specific question, but were not multiple-choice. Participants also completed normal exams for the course. Importantly, in the same academic year, two groups were tested: one group carried out practice tests after each lecture, another did not. Final test performance was significantly higher (~13%) for the retrieval practice group relative to the control group. Finally, McDaniel and colleagues (2011) presented regular 'quizzes' (multiple choice questions with feedback) to secondary school science students, showing average increases in final exam performance of ~13%.

In sum, studies show that final exam performance in both secondary school and university can be improved by embedding regular testing at the beginning or end of classes/lectures for psychological, statistical, and scientific knowledge. One key question is whether similar grade increases can be seen for subjects where exams are more open-ended or consist of extended essays, where the structure of an essay and the clarity of writing contribute more to the final grade relative to short-answer or multiple-choice questions. However, even under such conditions, it is likely that retrieval practice could still be used to build up base-level knowledge about a given topic.

WHY DOES RETRIEVAL PRACTICE WORK?

Why does repeated practice at retrieving information increase retention relative to repeated learning? This question is not just of theoretical importance, as understanding why retrieval practice works can help to guide how it should be implemented in real-world educational environments.

One way to think about how retrieval practice works is related to the concept of transfer: the extent to which learning one skill transfers to another skill. Typically, transfer effects in psychology tend to be small at best (Salomon & Perkins, 1989). If you want to improve at a particular skill, the best thing to do is practice that specific skill. This concept has been formalised in the field of memory into the framework of *transfer-appropriate processing*, or TAP (Morris *et al.*, 1977). This framework predicts that memory performance increases when the overlap between the mental processes recruited at learning and retrieval increase.

How does this relate to retrieval practice? Put simply, if you want to get better at retrieving information, you need to practice retrieving that information. Whereas re-studying of a prose passage might lead to more fluent reading of the text, retrieving the material will lead to more fluent retrieval later in time.

If retrieval practice worked solely on the basis of TAP, we would not expect to see transfer effects to other testing situations. As previously discussed, the manner of testing during retrieval practice and final test has a surprisingly small effect on final test performance (Carpenter & DeLosh, 2006; Glover, 1989). Further, TAP might predict that the more specific the retrieval practice, for example multiple choice questions rather than free recall, the greater the benefits at final test (presuming similar final test conditions). This does not appear to be the case, as free recall – where participants are required to retrieve as much as possible about a given topic with few retrieval cues – appears to produce larger retrieval practice effects than multiple choice questions (Carpenter & DeLosh, 2006). Thus, although TAP is likely to play a role in generating the retrieval practice effect, the 'far' transfer effects seen suggest that it cannot be the only source of the effect.

Given the large effects seen for free recall, a second possible explanation relates to *elaborative encoding* (Craik & Tulving, 1975), where memories are more likely to be retrieved when they are associated with multiple pre-existing memories or knowledge. Elaborative encoding can be used as a mnemonic device, where new material is explicitly linked to pre-existing knowledge. These links provide multiple routes to retrieval of the new information, increasing the probability of retrieving the information at a later point in time. The idea here is that free recall allows the student to form more links between the newly learnt information and other knowledge structures during the (practice) retrieval process. Free recall works particularly well for this as it is less structured than, for example, multiple choice questions and hence has the potential to form a wider variety of links.

A further benefit of retrieval practice, and particularly free recall, is that it strengthens the organisational structure of the newly learnt material (Zaromb & Roediger, 2010). Retrieval allows for links to be made between new and pre-existing knowledge, and, during that process, the new material is better integrated and structured. For example, if reading a prose passage that involves a short story, retrieval practice might allow the student to work out the structure of the story line, allowing for a more systematic search of their knowledge at a later time point.

Finally, retrieval practice also appears to help students to know more about what they know, a process referred to as metacognition. Often, when we retrieve a memory, we are able to explicitly state how sure we are that the information is correct. We are able to give *confidence judgements*. In a retrieval practice setting, participants are asked to retrieve newly learnt information. Subsequent to this, they can then be explicitly asked how confident they are that the information has been retrieved correctly. If provided with feedback, participants are able to direct their attention to the incorrect items, improving performance specifically for those items (Butler *et al.*, 2008). Importantly, in the same study, confidence increased for information that was initially retrieved successfully but which participants reported as 'low confidence'. Participants were able to use the feedback to correct their 'metacognitive errors', such that in the future they were not just able to retrieve the information correctly, but also to 'know' it was correctly retrieved. This improvement in metacognition has important implications for student anxiety. Retrieval practice not only improves performance, but also improves the overall confidence of students at final test. This accords with the high satisfaction levels which students report for real-world courses that use retrieval practice as a study aid (Leeming, 2002; McDaniel *et al.*, 2011).

Retrieval practice is a simple tool for boosting long-term retention, although the processes which produce the effect are likely multifaceted. The main driver is likely related to transfer-

appropriate processing – if you want to get better at retrieving information then you should practice retrieving that information. Agarwal *et al.* (2014) refer to this as focussing on 'getting information out of' as opposed to 'getting information into' students' heads. However, retrieval practice also appears to increase the chances of elaborative encoding, providing multiple routes to retrieval. Further, the practice does not just improve memory performance, it also improves the organisation of knowledge, student metacognition and overall confidence. Thus, retrieval practice appears to drive multiple learning mechanisms that lead to improvements on a number of important educational measures.

WHEN DOESN'T RETRIEVAL PRACTICE WORK?

Retrieval practice is clearly an effective educational tool that can be used to improve students' ability to retain and retrieve educational material. However, given the literature discussed, one might legitimately ask whether there are circumstances where retrieval practice does not work. What are the boundary conditions for the effect? One potentially relates to the complexity of both the learnt material and retrieval task (van Gog & Sweller, 2015). For example, with a subject where the material is complex and requires more 'critical examination', and the manner of testing is essay-based, there is perhaps less of an opportunity for retrieval practice to have an effect. This is not to say that retrieval practice cannot still be useful in such settings; the learning of any complex material can be aided by increases in the retrievability of the subject matter. However, this retrievability might have less of an impact on a student's final grade relative to subjects with less complexity that are tested in a more structured manner (eg, with multiple choice questions).

One might also ask whether retrieval practice helps to promote a true 'understanding' of a given topic. If the exams that contribute to final degree grades are taken as a reasonable measure of a student's understanding of a topic, then this does appear to be the case (as seen in the improvements in exams scores in Leeming, 2002; Lyle & Crawford, 2011; McDaniel *et al.*, 2011). A further way to address this is to empirically test the extent to which participants are able to use newly learnt knowledge in a novel situation. Butler (2010) presented prose passages to participants and tested their ability to make inferences; for example, after repeated retrieval of a prose passage about bats, participants were asked the following: 'the US military is looking at bat wings for inspiration in developing a new type of aircraft. How would this new type of aircraft differ from traditional aircrafts like fighter jets?'. Participants showed better performance in these inferential questions following repeated retrieval practice for the specific learnt material.

Retrieval practice has been shown to decrease performance in certain situations. For example, if we rapidly switch between learning and retrieving information in a laboratory based task, decrements in memory performance can be shown (Davis *et al.*, 2017). However, in real-world settings such rapid switching between learning and retrieving would be difficult to implement, and is unlikely to occur naturally, so such findings are more theoretically than practically relevant. Finally, the study that catalysed research into this effect found better performance for repeated learning than repeated retrieval when the final test was taken five minutes afterwards (Roediger & Karpicke, 2006). This suggests that if students are about to take an exam, restudying the material may actually be more beneficial than retrieval practice. However, what is perhaps surprising is the ubiquity of settings where retrieval practice does work. It is a psychological finding that is remarkably impervious to the precise laboratory conditions that it was originally tested in, and has clear pedagogical value.

HOW CAN I USE RETRIEVAL PRACTICE?

I have discussed whether and how retrieval practice works, but how can we use it when teaching? Here, I present practical advice, based on the empirical literature, of how to use retrieval practice to maximally benefit student learning.

First, is it practical to lose time at the beginning or end of every lecture or seminar in order to test participants' knowledge of the learnt material? The answer to this is yes. The improved rates of retention (~13%) in studies that have used retrieval practice in the real-world, coupled with the minimal amount of time needed (5-10 minutes per session) strongly support the use of retrieval practice. Put another way, it is better to spend 5-10 minutes to ensure students remember what you have just covered, rather than the same amount of time covering new material that is likely to be forgotten.

Before I discuss the specifics of using retrieval practice during a lecture and seminar, I present some general advice:

1. Retrieval practice should always be 'low-stakes'. Students should be made explicitly aware that they are not being judged or graded based on their response. If they understand that retrieval practice is part of the learning experience, they are known to report high levels of satisfaction (Leeming, 2002; McDaniel *et al.*, 2011).
2. Feedback should always be provided after retrieval practice. Evidence shows that feedback (irrespective of whether the participants were correct or not) improves final test performance (Butler *et al.*, 2008).
3. Space out repeated retrieval practice. For example, test material at the end of one lecture and the same material again at the beginning of the next lecture. The spacing effect is another well-known tool for boosting memory performance in real-world educational environments (Sobel *et al.*, 2011), and can be easily combined with retrieval practice to maximise long-term retention.
4. Interleave retrieval practice. For example, in a two hour lecture, test material from the first hour after a half-time break and then test some of the same material, along with the material learnt in the second half of the lecture, at the end of the lecture. The second testing session 'interleaves' material from the two halves of the lecture. Along with the spacing effect, interleaving is known to boost memory performance (Rohrer & Taylor, 2007) and can again be readily combined with retrieval practice.

With this general advice, how might retrieval practice be used in a typical lecture? Here I presume the teaching of a larger group of students (eg, > 50) where one-to-one interactions are more difficult, and students are less inclined to answer direct questions verbally. The key to effective retrieval practice is to ensure that all students in this environment are actively engaging in the retrieval of learnt material. One way to do this is with 'clickers', or the use of online polling websites (eg, *https://www.mentimeter.com/*). This allows the lecturer to keep track of the number of responses per question, such that they can encourage participation from every student; eg, one only moves on to the next question when the response rate is > 95%. These methods work well using multiple choice style questions, particularly when using clickers that have a limited range of response options (eg, four buttons). Note that although free recall shows the largest retrieval practice effect, any form of active retrieval is still beneficial (Carpenter & DeLosh, 2006), so multiple choice questions can work well in this setting. Having short testing sessions (eg, four questions) at the beginning and end of each lecture, testing material from both the previous and current session respectively, can work effectively. Lecturers can typically spend 5-10 minutes at the beginning and end of lectures 'recapping' what has been learnt; instead, one might consider replacing these 'recaps' – which is essentially 'restudying' – with retrieval practice. This would ensure students are actively engaged in recapping what they have learnt (via active retrieval). Critically, at the end of each retrieval session, one ought to provide feedback to the whole group on what the correct answer was, and why it was the correct answer.

In a seminar setting, where there are typically fewer students (eg, 5-20), there is more scope for one-to-one interaction with students. This provides greater flexibility in relation to the

type of retrieval practice in which students can engage. Given the evidence, free recall would be ideal (Carpenter & DeLosh, 2006). For example, in this setting, one could encourage students to write down what they remember learning during the seminar, or ask specific short-answer questions. If suitable, one might ask students what their answers were and provide specific feedback on these answers. Regardless, it is important to ensure feedback is provided to all students such that they are able to individually compare their answers with the 'correct' answer. Interestingly, retrieval practice can also work for material that has yet to be learnt (Arnold & McDermott, 2013). Asking students to 'guess' the correct answer to a question can stimulate future learning, leading to increased long-term retention. One might consider starting a seminar with questions about the material to be covered. This can not only be an effective way to encourage future learning, but also a means to appropriately gauge what the student cohort already knows about the topic.

Retrieval practice is a simple tool that can be used in a variety of settings. Although there is evidence that specific ways of implementing retrieval practice maximise memory performance on final test, the effect is remarkably resilient to how it is implemented. As long as students are given an opportunity to engage in low-stakes, active, effortful retrieval of educational material they are likely to remember that information better in the long term. Thus, retrieval practice can easily be adapted to suit an individual's teaching style, and the educational environment in which they find themselves. It can also replace certain aspects of a typical lecture or seminar (eg, 'recapping' at the end of a lecture) such that it can be cost neutral in terms of time.

CONCLUSION

Practicing retrieval is beneficial to students. Most notably, it improves their performance on exams. It also impacts on a range of other important measures related to the way students organise and understand material, and their confidence in tackling the material. Although we still do not fully understand exactly why retrieval practice works, it is likely to affect multiple learning mechanisms that all contribute to the substantial improvements in test performance seen in both laboratory and real-world educational environments. It can be easily embedded in both a lecture and seminar setting, and I have presented concrete advice about how best to achieve this. In sum, it is difficult to imagine an educational setting where retrieval practice could not be used, and would not result in improvements to students' long-term retention, final course grades, course satisfaction, and exam-related stress.

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