Journal of Applied Research in Memory and Cognition 1 (2012) 257–259

Contents lists available at SciVerse ScienceDirect

Journal of Applied Research in Memory and Cognition

journal homepage: www.elsevier.com/locate/jarmac

Commentary

Tests enhance learning—Compared to what?

Nate Kornell[a,*], Veronica C. Rabelo[b], Patricia Jacobs Klein[c]

[a] Department of Psychology, Williams College, United States
[b] Department of Psychology, University of Michigan, United States
[c] Department of Mathematics, University of Michigan, United States

ARTICLE INFO

Article history:
Received 5 October 2012
Accepted 7 October 2012

Keywords:
Testing
Retrieval
Learning
Education
Control condition

Paclitaxel is a chemotherapy drug that has been used to treat cancer since the 1960s. It is relatively inexpensive because there is a generic version. In recent years, more expensive drugs have been developed to replace paclitaxel. After successful clinical trials, both Abraxane and Ixempra have been approved by the FDA. For their makers, this is the good news. The bad news is that, according to a study released in June 2012, neither of the newer drugs works as well as paclitaxel (Berkrot, 2012).

New drugs are initially compared to placebos. But in medicine, being more effective than the placebo is not enough. To become a recommended treatment, a new drug should be better than the current treatment. The same is true in education. Roediger and Pyc (2012) make this point clear: "The gold standard of educational innovation for any kind of new educational technique should be a strong research base showing that the new method produces positive results relative to standard practice (Whitehurst, 2010)."

Roediger and Pyc's (2012) article ably describes three principles that enhance learning: distributed practice, explanatory questioning, and the one we focus on here, test-enhanced learning. In the literature to date, the value of testing has been demonstrated by comparing tests to two other activities: restudying the same information in the same way as before, or not restudying at all (Roediger & Pyc). Tests appear to be better than restudying. But is restudying an effective standard practice, like paclitaxel, or is it more like a placebo? In this article, we consider the value of tests as compared to various different learning activities. We begin with an alternative that is all too common: doing nothing.

1. Is testing better than not studying?

Not studying is a common practice among some students. However, when testing is compared to not studying, it difficult to determine whether testing per se was beneficial, because tested information is also studied more than information in the non-studied control condition. Classroom studies showing that tests are more effective than not studying (e.g., McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011) are less convincing than classroom studies comparing testing to presentations of the same material (e.g., Roediger, Agarwal, McDaniel, & McDermott, 2011).

2. Is testing better than restudying in exactly the same way as before?

In most research on the value of tests, a test condition is compared to *exact repetition*: restudying (usually rereading) the same material in the same way one studied it before (e.g., Roediger & Karpicke, 2006).

Exact repetition can be ineffective. In multiple studies, reading a passage for a second time produced no measurable benefit compared to reading it once (e.g., Callender & McDaniel, 2009; Fritz, Morris, Bjork, Gelman, & Wickens, 2000). Rawson and Kintsch (2005) replicated this finding, but also found that a benefit of exact repetition emerged when there was a delay between repetitions (an example of the spacing effect; Dempster, 1988). Other studies have shown that restudying word pairs has no measurable impact

* Corresponding author at: 18 Hoxsey Street, Williamstown, MA 01267, United States. Tel.: +1 413 597 4486; fax: +1 413 597 2085.
E-mail address: nkornell@gmail.com (N. Kornell).

2211-3681/$ – see front matter
http://dx.doi.org/10.1016/j.jarmac.2012.10.002

on long-term learning once the pairs have been recalled at least one time (Karpicke & Roediger, 2008). Thus, like a placebo, exact repetition has limited long-term benefits.

Despite its limited value, exact repetition is a standard practice in some domains. For example, students tend to read the same passages from their textbooks, or their notes, multiple times. Convincing evidence has demonstrated that testing is more effective than restudying in real educational settings (e.g., McDaniel, Wildman, & Anderson, 2012; Roediger et al., 2011). Thus, students benefit from being tested instead of restudying via exact repetition.

3. Is testing better than studying the same information in a new way?

In some situations, exact repetition is not a standard practice. Lectures are one example. When teachers go over information that their students have been exposed to before (for instance, in a homework assignment), they usually present it in their own words, covering the parts they think are most important, which we refer to as *non-exact repetition*.

Is there evidence that testing is superior to non-exact repetition? Butler and Roediger (2007) examined learning in a simulated classroom in which participants viewed a lecture and then either read a lecture summary, took a multiple choice test, or took a short-answer test. The lecture summary, which served as a restudy condition, was a non-exact repetition of the lecture material. There was a testing effect—the short answer test produced more learning than the other conditions—which suggests that tests can be superior to non-exact repetition. Such an effect has been demonstrated in only a handful of studies, however (e.g., McDaniel, Anderson, Derbish, & Morrisette, 2007; McDaniel, Howard, & Einstein, 2009). Thus, there is some evidence that testing can be more effective than non-exact repetition, but more research is needed.

4. Is testing better than learning something new?

There is another activity that is quite common in classrooms: Presenting novel information. For every 10 min a teacher spends giving a quiz on previously studied information, he or she could present novel information instead.

We know of no published evidence in which one group studied and then took a test and another studied and then studied additional novel information that was never shown to the first group. Such a study would have to measure learning across all of the information that *could have* been studied, even if the final criterion test included information the first group had not studied. Cognitive psychologists may be loath to compare groups that have studied different amounts of information, but teachers are under no such constraint; they are limited by the amount of time available for instruction, not the amount of information they cover.[1]

5. Is testing better than doing something else?

In general, students learn more when they are active than when they are passive. There are many ways to encourage active learning. Yet almost all studies of the testing effect have compared testing to passive reading. One exception is a study by Karpicke and Blunt (2011), who found that testing is more effective than concept mapping, which typically involves active learning. (However, Karpicke & Blunt's concept mapping condition was not significantly more effective than restudying.)

Many effective learning techniques have not been compared to testing. For example, Roediger and Pyc (2012) describe the benefits of self-explanation and elaborative interrogation. Because study time is a limited resource, a teacher might have to choose one of these activities or a test. As the case of paclitaxel makes clear, it is dangerous to make assumptions when three proven treatments are pitted against each other. It is worth noting that these activities are related—one reason self-explanation is beneficial is that, like a test, it makes people try to retrieve information from memory—although they are not identical. Thus, it seems premature to make blanket recommendations of testing if it would come at the expense of activities like these (to be clear, Roediger & Pyc make no such recommendation).

One way to address the value of tests versus "something else" is to examine what happens when a teacher takes the advice to do more testing. For example, one semester Frank Leeming decided to give short quizzes at the beginning of each of his classes (Leeming, 2002). He minimized the impact of lost lecture time by cutting the least valuable elements of his lectures. Compared to previous semesters, he found that grades improved. Lyle and Crawford (2011) reported that a section of a statistics class that was quizzed every day achieved better exam scores (86%) than a section that was not (78%).

In the first author's experience, the biggest effect of daily quizzes may be that they motivate effortful studying and punctual class attendance. It is difficult to disentangle these benefits from the direct benefit of the tests. However, at least one study has shown that students who took a quiz they were expecting learned more than students who expected a quiz but did not take one, suggesting that changes in study behavior may not fully explain the benefit of testing (Haynie, 1997).

In summary, there is some evidence that learning increases when teachers follow the advice "test more," but more evidence is needed. Increased studying in anticipation of tests may help explain the benefit of tests.

6. Practical applications

When teachers are told that they should do more testing, they often protest that doing so would take time away from other valuable learning activities. Is testing better than these activities? The evidence we have reviewed suggests that, like most scientific questions, the answer is "it depends."

We recommend that teachers test students in class, and students test themselves outside class, whenever the alternative is exact repetition. There is some evidence that testing is more effective than non-exact repetition as well. Every teacher's toolbox should include tests as learning events.

But testing has not been compared to many common learning activities, such as learning new information or self-explanation. In these cases, recommending that teachers stop what they have been doing and replace it with testing seems premature. Doing so would require (a) knowing what activity would be sacrificed in favor of time spent testing and (b) having evidence on hand comparing testing to that activity. Although accumulating such evidence would be a major undertaking, it may be necessary if testing is to avoid the fate of many other educational recommendations that have not made the transition from the laboratory to the classroom.

Acknowledgments

Andrew C. Butler, Bridgid Finn, Sean H.K. Kang, and Alexander LaTourrette made valuable comments on a draft of this article.

[1] An advantage of distributed practice is that unlike testing, it involves rearranging learning time, rather than increasing it; Dempster, 1988.

References

Berkrot, B. (2012, June). Costly newer drugs no better in breast cancer study. *Reuters*, Retrieved from http://www.reuters.com/article/2012/06/04/us-cancer-breast-paclitaxel-idUSBRE85303420120604

Butler, A. C., & Roediger, H. L. (2007). Testing improves long-term retention in a simulated classroom setting. *European Journal of Cognitive Psychology*, *19*, 514–527. http://dx.doi.org/10.1080/09541440701326097

Callender, A. A., & McDaniel, M. A. (2009). The limited benefits of rereading educational texts. *Contemporary Educational Psychology*, *34*(1), 30–41. http://dx.doi.org/10.1016/j.cedpsych.2008.07.001

Dempster, F. N. (1988). The spacing effect: A case study in the failure to apply the results of psychological research. *American Psychologist*, *43*(8), 627–634. http://dx.doi.org/10.1037/0003-066X.43.8.627

Fritz, C. O., Morris, P. E., Bjork, R. A., Gelman, R., & Wickens, T. D. (2000). When further learning fails: Stability and change following repeated presentation of text. *British Journal of Psychology*, *91*, 493–511.

Haynie, W. J. (1997). Effects of anticipation of tests on delayed retention learning. *Journal of Technology Education*, *9*(1), 20–30.

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than elaborative studying with concept mapping. *Science*, *331*(6018), 772–775. http://dx.doi.org/10.1126/science.1199327

Karpicke, J. D., & Roediger, H. L. (2008). The critical importance of retrieval for learning. *Science*, *319*(5865), 966–968. http://dx.doi.org/10.1126/science.1152408

Leeming, F. C. (2002). The exam-a-day procedure improves performance in psychology classes. *Teaching of Psychology*, *29*(3), 210–212. http://dx.doi.org/10.1207/S15328023TOP2903_06

Lyle, K. B., & Crawford, N. A. (2011). Retrieving essential material at the end of lectures improves performance on statistics exams. *Teaching of Psychology*, *38*(2), 94–97. http://dx.doi.org/10.1177/0098628311401587

McDaniel, M., Anderson, J., Derbish, M., & Morrisette, N. (2007). Testing the testing effect in the classroom. *European Journal of Cognitive Psychology*, *19*, 494–513.

McDaniel, M., Howard, D., & Einstein, G. (2009). The read–recite–review study strategy: Effective and portable. *Psychological Science*, *20*(4), 516–522. http://dx.doi.org/10.1111/j. 1467-9280.2009.02325.x

McDaniel, M. A., Agarwal, P. K., Huelser, B. J., McDermott, K. B., & Roediger, H. L. (2011). Test-enhanced learning in a middle school science classroom: The effects of quiz frequency and placement. *Journal of Educational Psychology*, *103*(2), 399–414. http://dx.doi.org/10.1037/a0021782

McDaniel, M. A., Wildman, K. M., & Anderson, J. L. (2012). Using quizzes to enhance summative-assessment performance in a web-based class: An experimental study. *Journal of Applied Research in Memory and Cognition*, *1*, 18–26.

Rawson, K. A., & Kintsch, W. (2005). Rereading effects depend on time of test. *Journal of Educational Psychology*, *97*(1), 70–80. http://dx.doi.org/10.1037/0022-0663.97.1.70

Roediger, H. L., Agarwal, P. K., McDaniel, M. A., & McDermott, K. B. (2011). Test-enhanced learning in the classroom: Long-term improvements from quizzing. *Journal of Experimental Psychology: Applied*, *17*(4), 382–395. http://dx.doi.org/10.1037/a0026252

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, *17*(3), 249–255. http://dx.doi.org/10.1111/j. 1467-9280.2006.01693.x

Roediger, H. L., & Pyc, M. (2012). Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice. *Journal of Applied Research in Memory and Cognition*.

Whitehurst, G. J. (2010). Education research: Past, present, future. In *Policy perspectives*. San Francisco, CA: WestEd.