Applying Learning Principles from Cognitive Science to Teaching

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How do we learn?

- Over 100 years of research in cognitive science has sought to discover effective learning techniques and environments.

- How can we promote *durable* learning?

Key findings for improving instruction

- Small changes in the learning environment can lead to dramatic improvements in student outcomes.

- Our intuitions about learning are often wrong .

An example: Art history class

- Your job is to teach students the painting styles of two artists: Pessani and Juras. You want them to be able to encounter a new painting and identify which artist it was created by.

- How should you present the examples of different artists' paintings?

- Two presentation schedules to examine: Massed and Spaced learning.

Massed learning

Pessani

Pessani

Pessani

Juras

Juras

Juras

Spaced learning

Pessani

Juras

Pessani

Juras

Pessani

Juras

Which is better for learning?

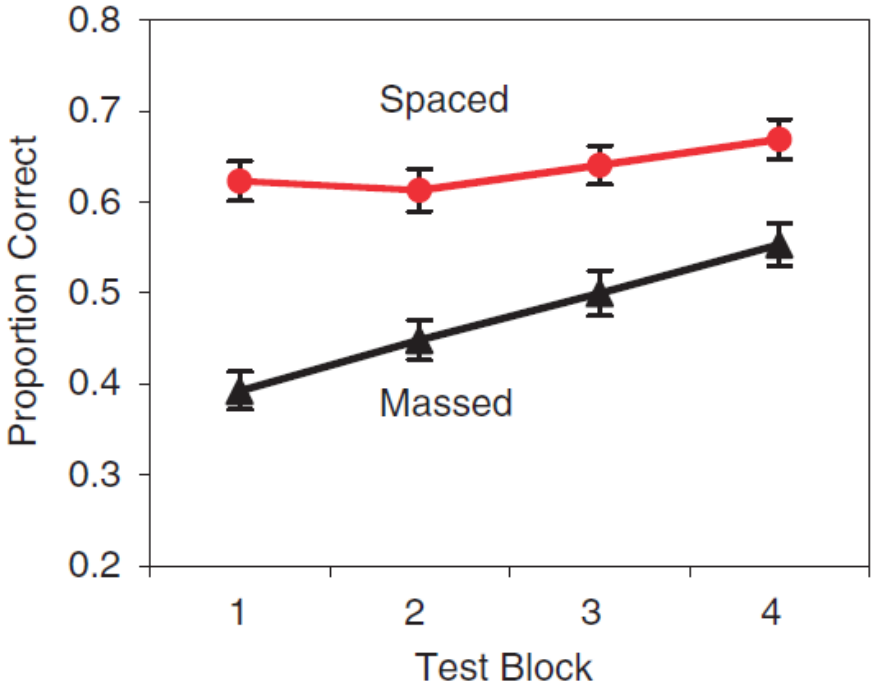
- A massed learning schedule or a spaced learning schedule?

Research says… Spaced learning!

Kornell & Bjork (2008): Across four learning blocks, students learned to identify 12 artists' painting styles much better on a spaced learning schedule.

This wasn't just about memorizing a select number of paintings.

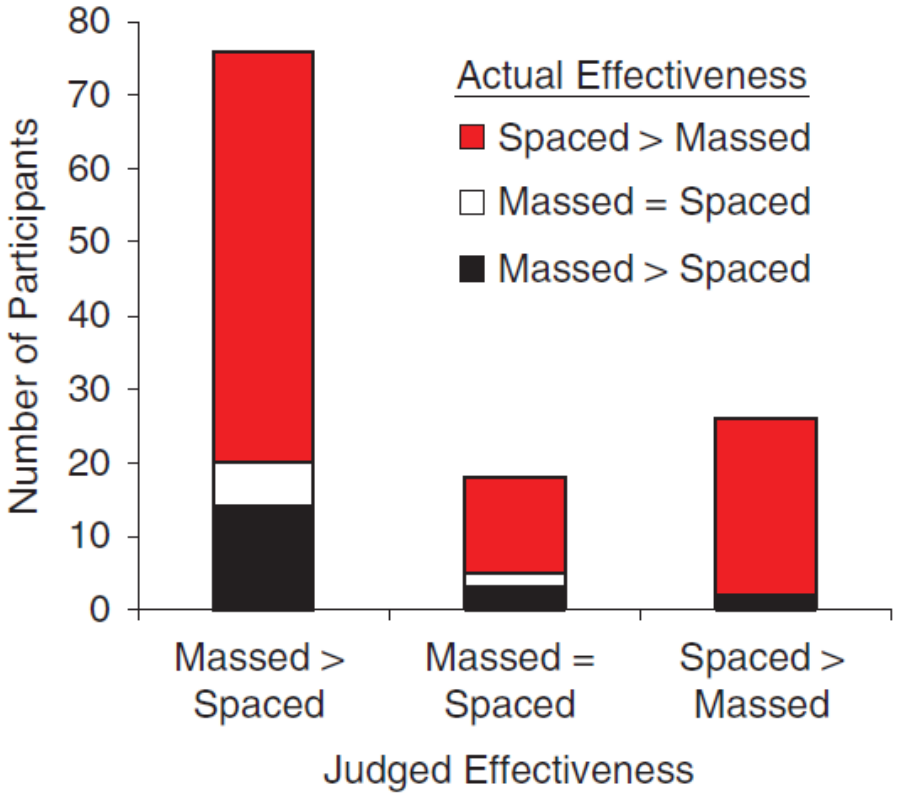
Students were able to extract common patterns, and generalize and transfer their knowledge of these patterns to paintings that they had never seen before!



Research says… Spaced learning!

Kornell & Bjork (2008): Students reported that they *felt* like they learned better on a massed learning schedule, even though this wasn't the case!

Students weren't reliable in their own assessments of how well they were learning the material.



In our own lab…

Vlach & Sandhofer (2012): Young children learn science concepts, such as the food chain, better on a spaced learning schedule. They can extract their new knowledge of the food chain and apply it to food chains in other geographical contexts.

Spaced/Distributed Learning

- Over 1,000 published studies have observed a spacing effect, and that number is growing exponentially! It's the most replicated effect in all of psychological science.

- This is the ***most promising*** body of work from psychological science for improving teaching practices.

Why?

- The most potent learning events require students to retrieve and use previously learned knowledge – that's harder to do!

“Desirable Difficulties”

- Implement these short-term impediments in learning to make practice more effortful.

- Individuals mistakenly rely on the immediate access to knowledge in order to determine the long-term memory retention and the transfer of such knowledge to different contexts.
  - What this means: just because you are performing well during learning (e.g., spitting back the answers quickly and easily right after learning it), doesn’t mean you’re learning it better for the long-term!

What should we keep in mind about learning principles?

- Recent scholarly review in *Psych Science,* around 50 pages long:
  - Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). **Improving students' learning with effective learning techniques: promising directions from cognitive and educational psychology**. *Psychological Science in the Public Interest, 14(1)*, 4-58.

- Much, much shorter version of this review, complete with illustrations, published the same year in *Scientific American Mind,* called "What works, what doesn't." Dunlosky et al., (2013)
  - **Click here for the web link to this article.**

Learning Techniques

- Distributed (Spaced) Learning
- Interleaved Learning
- Practice Testing
- Rereading
- Imagery Use for Text Learning
- Mnemonics
- Highlighting
- Summarization
- Self-Explanation
- Elaborative Interrogation

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5 = durable learning

5 = not effective

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Misconceptions on Learning

- “Cramming works for me.”
- “Once I learn the material, surely I will remember it later.”
- “Making errors impedes my learning.”
- “Rereading and highlighting work best for me.”
- “I learn the most when the learning comes most easily to me.”

Misconceptions on Learning

"Cramming works for me."

Spacing as the friend of both memory and induction in young and older adults

Article *in* Psychology and Aging · June 2010

DOI: 10.1037/a0017807 · Source: PubMed

4 authors:

Nate Kornell
Williams College
56 PUBLICATIONS **2,220** CITATIONS

Alan Castel
University of California, Los Angeles
74 PUBLICATIONS **2,638** CITATIONS

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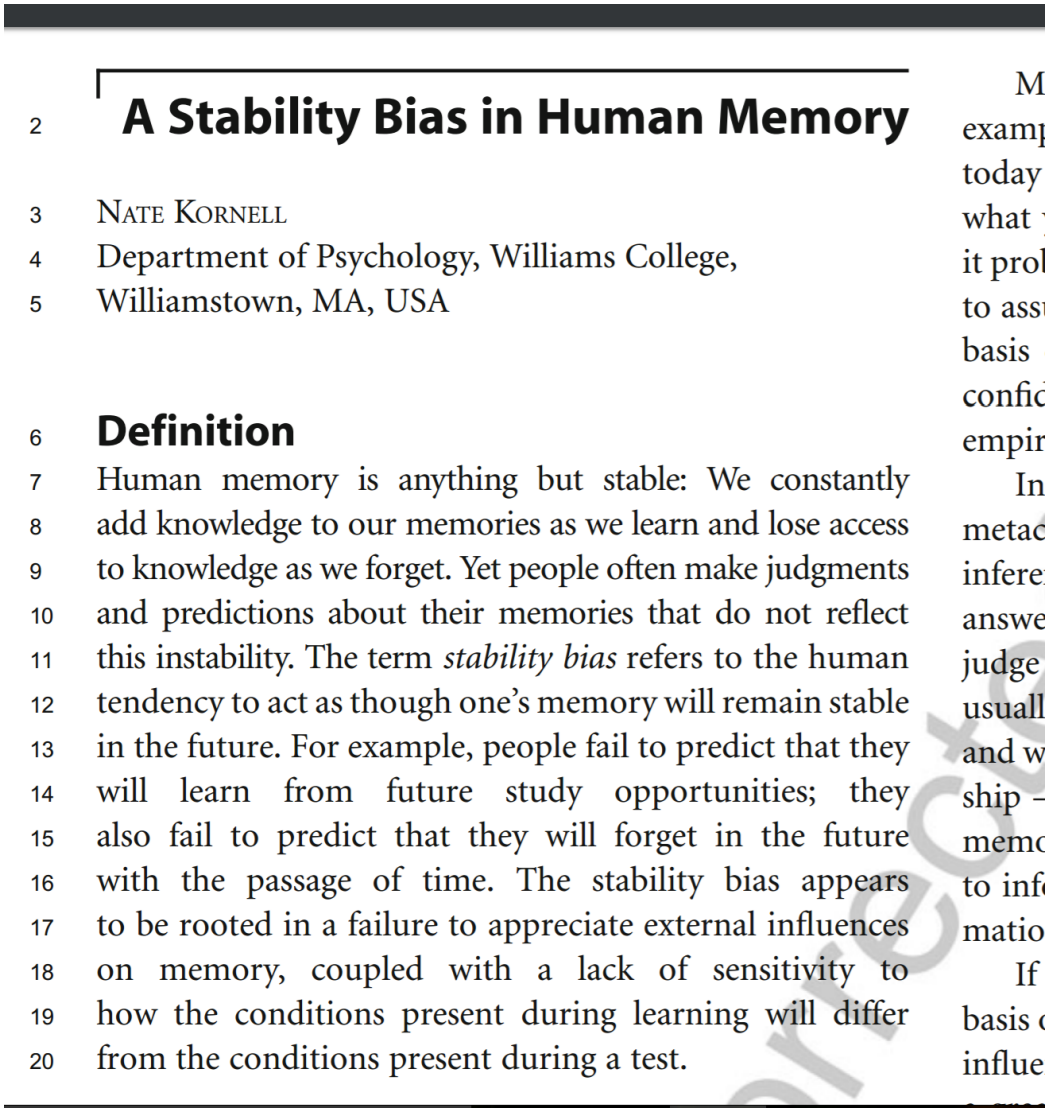

2 **A Stability Bias in Human Memory**

3 NATE KORNELL
4 Department of Psychology, Williams College,
5 Williamstown, MA, USA

6 **Definition**

7 Human memory is anything but stable: We constantly
8 add knowledge to our memories as we learn and lose access
9 to knowledge as we forget. Yet people often make judgments
10 and predictions about their memories that do not reflect
11 this instability. The term *stability bias* refers to the human
12 tendency to act as though one's memory will remain stable
13 in the future. For example, people fail to predict that they
14 will learn from future study opportunities; they
15 also fail to predict that they will forget in the future
16 with the passage of time. The stability bias appears
17 to be rooted in a failure to appreciate external influences
18 on memory, coupled with a lack of sensitivity to
19 how the conditions present during learning will differ
20 from the conditions present during a test.

Misconceptions on Learning

"Making errors hinders my learning."

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ıg, Memory, and Cognition
Vol. 35, No. 4, 989–998

0278-7393/09/$12.00 DOI: 10.1037/a0015729

Unsuccessful Retrieval Attempts Enhance Subsequent Learning

Nate Kornell, Matthew Jensen Hays, and Robert A. Bjork
University of California, Los Angeles

Taking tests enhances learning. But what happens when one cannot answer a test question—does an unsuccessful retrieval attempt impede future learning or enhance it? The authors examined this question using materials that ensured that retrieval attempts would be unsuccessful. In Experiments 1 and 2, participants were asked fictional general-knowledge questions (e.g., "What peace treaty ended the Calumet War?"). In Experiments 3–6, participants were shown a cue word (e.g., *whale*) and were asked to guess a weak associate (e.g., *mammal*); the rare trials on which participants guessed the correct response were excluded from the analyses. In the *test* condition, participants attempted to answer the question before being shown the answer; in the *read-only* condition, the question and answer were presented together. Unsuccessful retrieval attempts enhanced learning with both types of materials. These results demonstrate that retrieval attempts enhance future learning; they also suggest that taking challenging tests—instead of avoiding errors—may be one key to effective learning.

Keywords: memory, learning, testing, retrieval, education

ıe variety of ways to enhance learning are not easily enumer-
or categorized, but one general and enduring principle is that

ment than do study events of whether information is likely to be
recallable in the future (e.g., T. O. Nelson & Dunlosky, 1991). A

Misconceptions on Learning

- "I learn the most when the learning comes most easily to me."

Making Things Hard on Yourself, But in a Good Way: Creating Desirable Difficulties to Enhance Learning

Elizabeth Ligon Bjork and Robert A. Bjork
University of California, Los Angeles

long-term retention and transfer.

Learning versus Performance

This apparent paradox is a new twist on an old and time-honored distinction in psychology—namely, the distinction between learning and performance. Performance is what we can observe and measure during instruction or training. Learning—that is, the more or less permanent change in knowledge or understanding that is the target of instruction—is something we must try to infer, and current performance can be a highly unreliable index of whether learning has occurred.

Learning Without Performance and Performance Without Learning

Decades ago, learning theorists were forced to distinguish between learning and performance because experiments revealed that considerable learning could happen across a period when no change was apparent in performance. In latent-learning experiments with animals, for example, periods of free exploration of a maze, during which the animal's behavior seemed aimless, were shown—once reward was introduced—to have produced considerable learning. Similarly, in research on motor skills, investigators found that learning continued across trials during which the build-up of fatigue suppressed performance.

More recently, a variety of experiments—some of which we summarize

Misconceptions on Learning

- "Rereading and highlighting work best for me."

What Doesn't Work

These techniques were rated as low utility because they are inefficient, ineffective or beneficial only for certain types of learning and for short periods of retention. Most students report rereading and highlighting, yet these techniques do not consistently boost performance, and they distract students from more productive strategies. Other methods mentioned below are just too time-consuming.

HIGHLIGHTING

Students commonly report underlining, highlighting or otherwise marking material. It is simple and quick—but it does little to improve performance. In controlled studies, highlighting has failed to help U.S. Air Force basic trainees, children and remedial students, as well as typical undergraduates. Underlining was ineffective regardless of text length and topic, whether it was aerodynamics, ancient Greek schools or Tanzania.

In fact, it may actually hurt performance on some higher-level tasks. One study of education majors found that underlining reduced their ability to draw inferences from a history textbook. It may be that underlining draws attention to individual items rather than to connections across items.

WHAT YOU SHOULD DO INSTEAD: Highlighting or underlining can be useful if it is the beginning of a journey—if the marked information is then turned into flash cards or self-tests. Given that student ability is also woefully underexplored. Most of the benefit of rereading appears to accrue from the second reading, with diminishing returns from additional repetitions. No experimental research has assessed it using materials from actual courses—ironic, given that this strategy is the one most commonly reported by students.

WHAT YOU SHOULD DO INSTEAD: Don't waste your time—in head-to-head comparisons, rereading fares poorly against more active strategies such as elaborative interrogation, self-explanation and practice testing.

Three less commonly used study techniques also fared poorly in our assessment. "Imagery for text learning" needs more evidence before it can be recommended, whereas "summarization" and "keyword mnemonic" appear to be ineffective and time-consuming.

In summarization, students identify a text's main points, excluding unimportant material. Whether it works is difficult to answer, as it has been implemented in many different ways. It is unknown whether summarizing small pieces of a text or large chunks of it works better or whether the length, readability or organization of the material matters.

With keyword mnemonics, imagery is used to enhance memory; for example, a student learning the French word *la dent*

Misconceptions on Learning

- Moving beyond single-minded, rapid-fire repetition to burn something into memory (massed practice), which is not good for long-term learning.
  - Conventional wisdom is “practice-practice-practice!”
  - These strategies give rise to feelings of fluency that are taken to be signs of mastery.
  - For true mastery or durability, these strategies are largely a waste of time.

Testing Effect (Retrieval Effect)

- *Roediger & Karpicke (2006)*

Research Article

Test-Enhanced Learning

Taking Memory Tests Improves Long-Term Retention

Henry L. Roediger, III, and Jeffrey D. Karpicke

Washington University in St. Louis

ABSTRACT—*Taking a memory test not only assesses what one knows, but also enhances later retention, a phenomenon known as the testing effect. We studied this effect with educationally relevant materials and investigated whether testing facilitates learning only because tests offer an opportunity to restudy material. In two experiments, students studied prose passages and took one or three immediate free-recall tests, without feedback, or restudied the material the same number of times as the students who received tests. Students then took a final retention test 5 min, 2 days, or 1 week later. When the final test was given after 5 min, repeated studying improved recall relative to repeated testing. However, on the delayed tests, prior testing produced substantially greater retention than studying, even*

the future than if they had not been tested. This phenomenon, called the testing effect, has been studied sporadically over a long period of time (e.g., Gates, 1917), but is not well known outside cognitive psychology.

Most experiments on the testing effect have been conducted in the verbal learning tradition using word lists (e.g., Hogan & Kintsch, 1971; Izawa, 1967; McDaniel & Masson, 1985; Thompson, Wenger, & Bartling, 1978; Tulving, 1967; Wheeler, Ewers, & Buonanno, 2003) or picture lists (Wheeler & Roediger, 1992) as materials. There have been a few experiments using materials found in educational contexts, beginning with Spitzer (1939; see too Glover, 1989, and McDaniel & Fisher, 1991). However, the title of Glover's article from 17 years ago still sums up the current state of affairs: "The 'testing' phenomenon: Not

Misconceptions of Testing

- Testing is often considered a bad thing. Why?
  - Testing can be stressful for test-takers
  - Testing takes substantial time away from teaching
  - Testing (especially multiple choice) misses conceptual understanding
  - Testing is used to make policy/funding and other decisions

- But, can testing help students *during* learning?

Formative vs. Summative Assessments

- Formative assessment: *monitor student learning* to provide ongoing feedback that can be used by instructors to improve their teaching and by students to improve their learning.
  - Low-stakes testing, such as short, frequent quizzes
  - Flash cards, study guides, etc.
  - Project proposals, rough drafts
  - Anything that makes you work a little harder during learning!

- Summative assessment: *evaluate student learning* at the end of an instructional unit by comparing it against some standard or benchmark.
  - Mid-terms
  - Final project paper
  - Final presentation

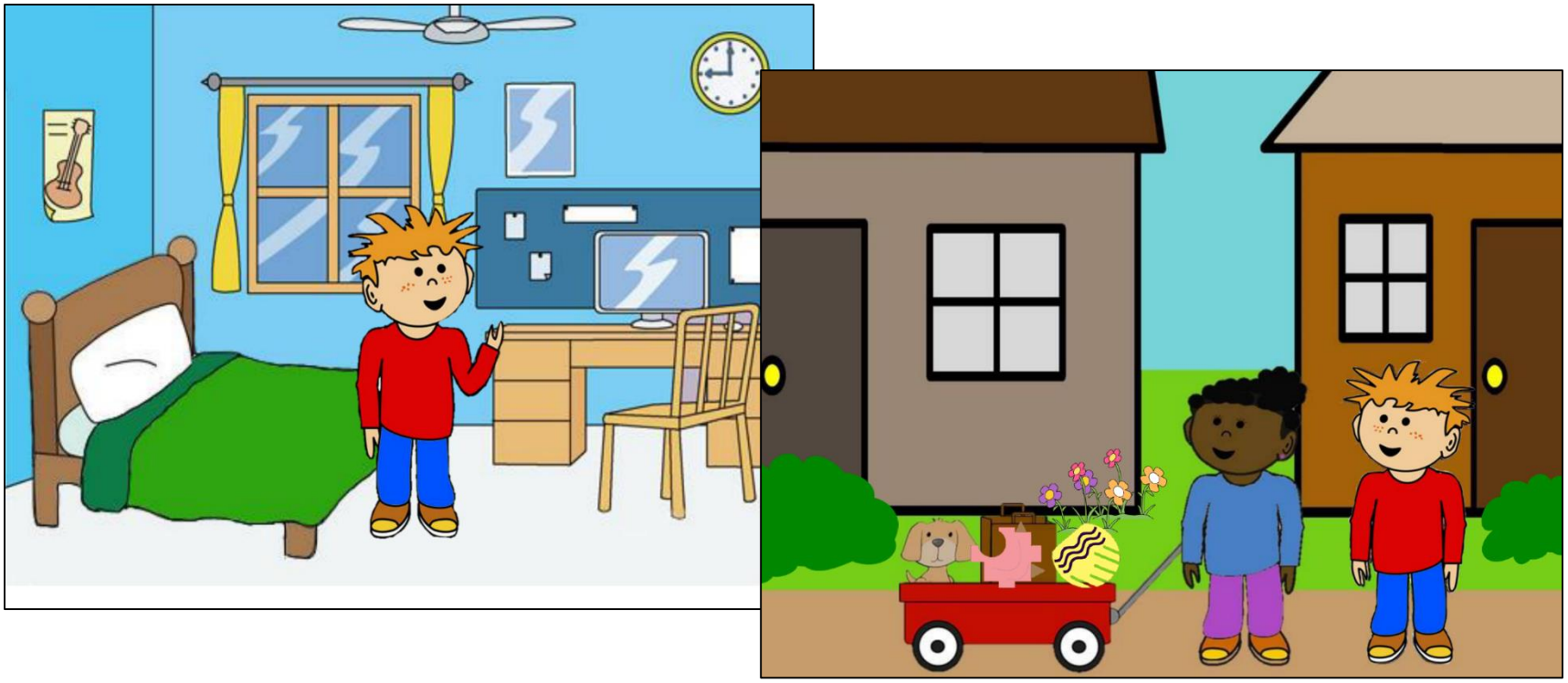
The key is: Retrieval!

- Retrieval, or actively attempting to retrieve information from long-term memory, is largely thought to be the mechanism behind the testing effect we observe in these studies
  - Strengthens the memory, makes it more accessible for the future
  - Actively interrupts forgetting

- Retrieval is also relevant for the spacing effect!
  - When you space out practice at a task, or interleave the practice of two or more subjects, ***retrieval is harder and feels less productive*****,** but the effort ***produces longer-lasting learning*** and enables more versatile application of it in later settings.

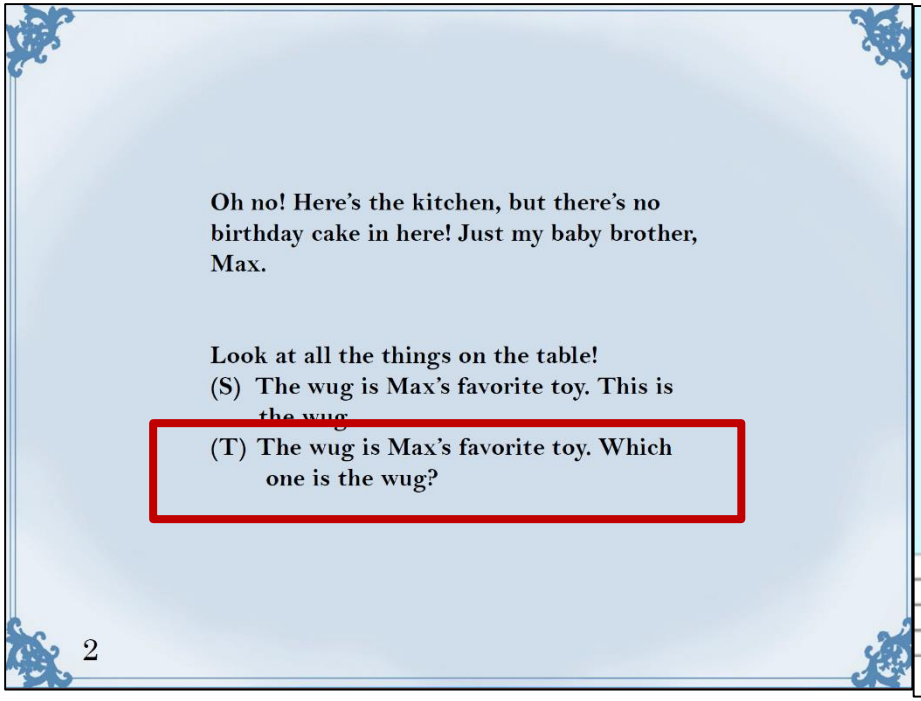
In our own lab…

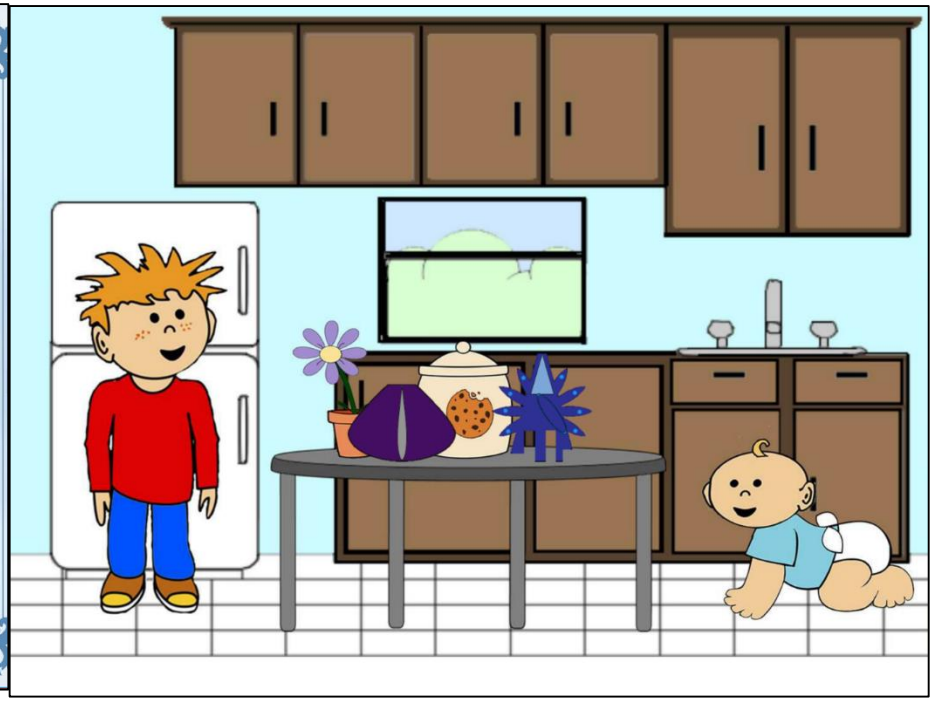
DeBrock & Vlach (In Preparation): Application of the testing effect and active retrieval in children's storybooks.



In our own lab…

DeBrock & Vlach (In Preparation): During storybook reading, children are asked to retrieve information learned in the context of a storybook narrative.





Take-home messages

- Engage your students in retrieval of previously learned information (active learning!).
- Inform students of effective learning techniques and study practices.
- Overcome misleading intuitions about how good learning occurs.

Some concluding thoughts…

"Learning happens when you think hard about subject content.

Probably."

-Rob Coe, CEM Durham University

Thank You!

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LEARNING, COGNITION, and DEVELOPMENT LAB

For more information, visit the Learning, Cognition, & Development Lab webpage: http://vlachlab.education.wisc.edu

Additional Resources

- Short summary article from *Scientific American Mind:* "What works, what doesn't." Dunlosky et al., (2013)

- **Excellent** book with many, many concrete examples, and a quick read, on desirable difficulties in the classroom, on the playing field, and all types of training:
  - ***Make It Stick: The Science of Successful Learning*****.** Brown, Roediger, & McDaniel (2014)