

Mechanisms of Memory: Enhancing Retention Through Repeated Retrieval

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**Collège de France
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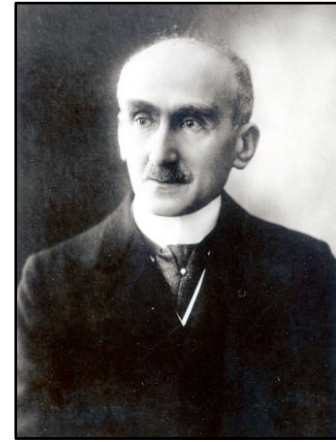


 **Washington**
University in St. Louis

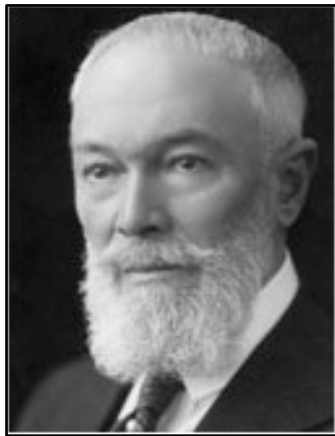
ARTS & SCIENCES



Théodule Ribot
(1839 - 1916)



Henri Bergson
(1859 - 1941)



Pierre Janet
(1859 - 1947)



Alfred Binet
(1857 - 1911)

Three Stages in the Learning/Memory Process



- Encoding: Original learning or acquisition of information
- Storage: Maintaining information over time
- Retrieval: Accessing stored information

Keys to Remembering

- Recoding: Converting information from one form to another (e.g., from words to images)
- Retrieval cues: Prompts to permit access to stored information
- Repeated retrieval: Practice in accessing knowledge to maintain it

1 4 9 1 6 2 5
3 6 4 9 6 4 8 1

- Recoding: Converting information from one form to another
- Key principle: Convert information to a form that is easier to remember

Squares of 1 to 9

1 4 9 16 25

36 49 64 81

Effectiveness of Mental Imagery

- Three conditions:

- Study 50 words

wheelchair

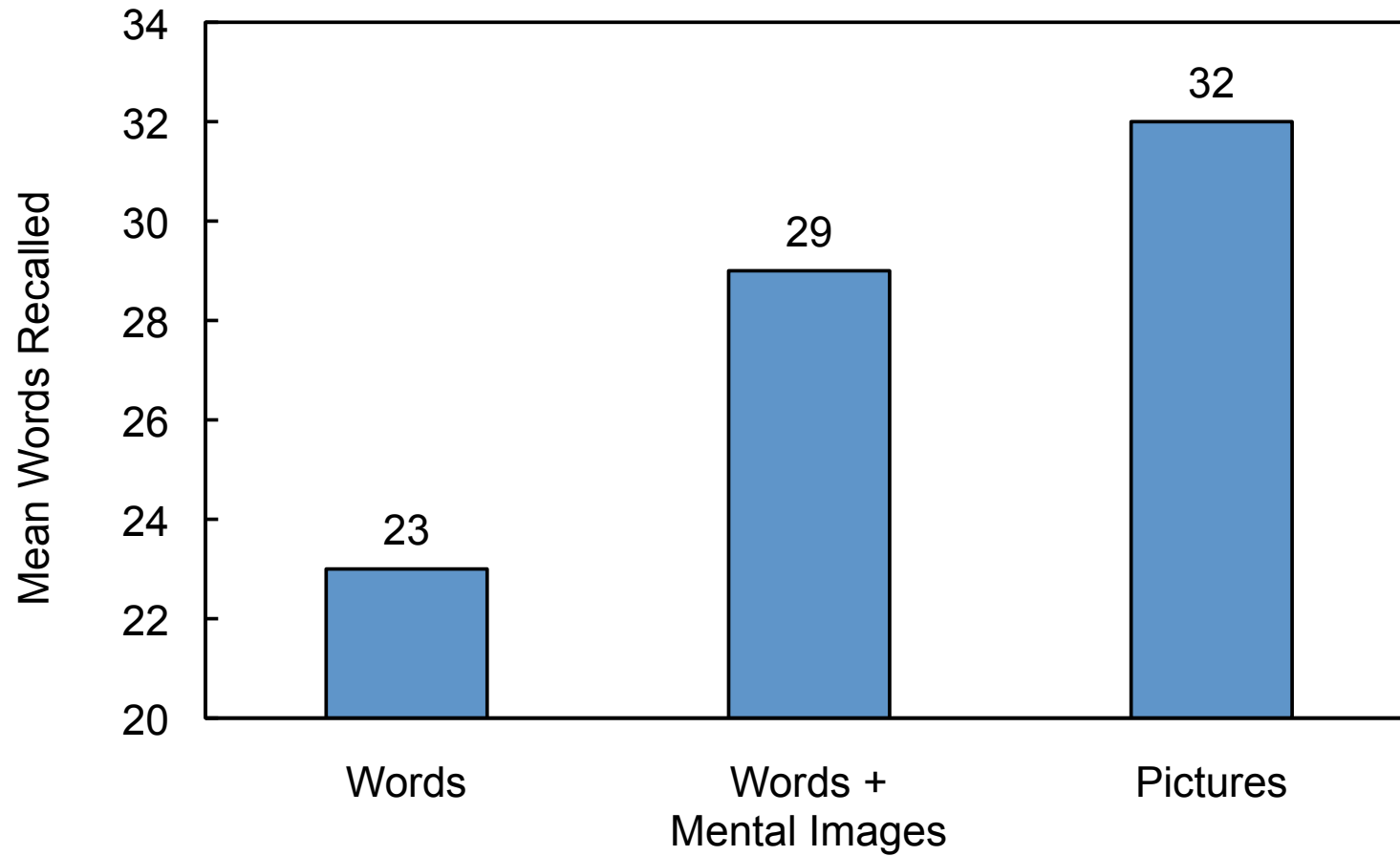
- Study 50 words, but create mental images

wheelchair

- Study 50 pictures

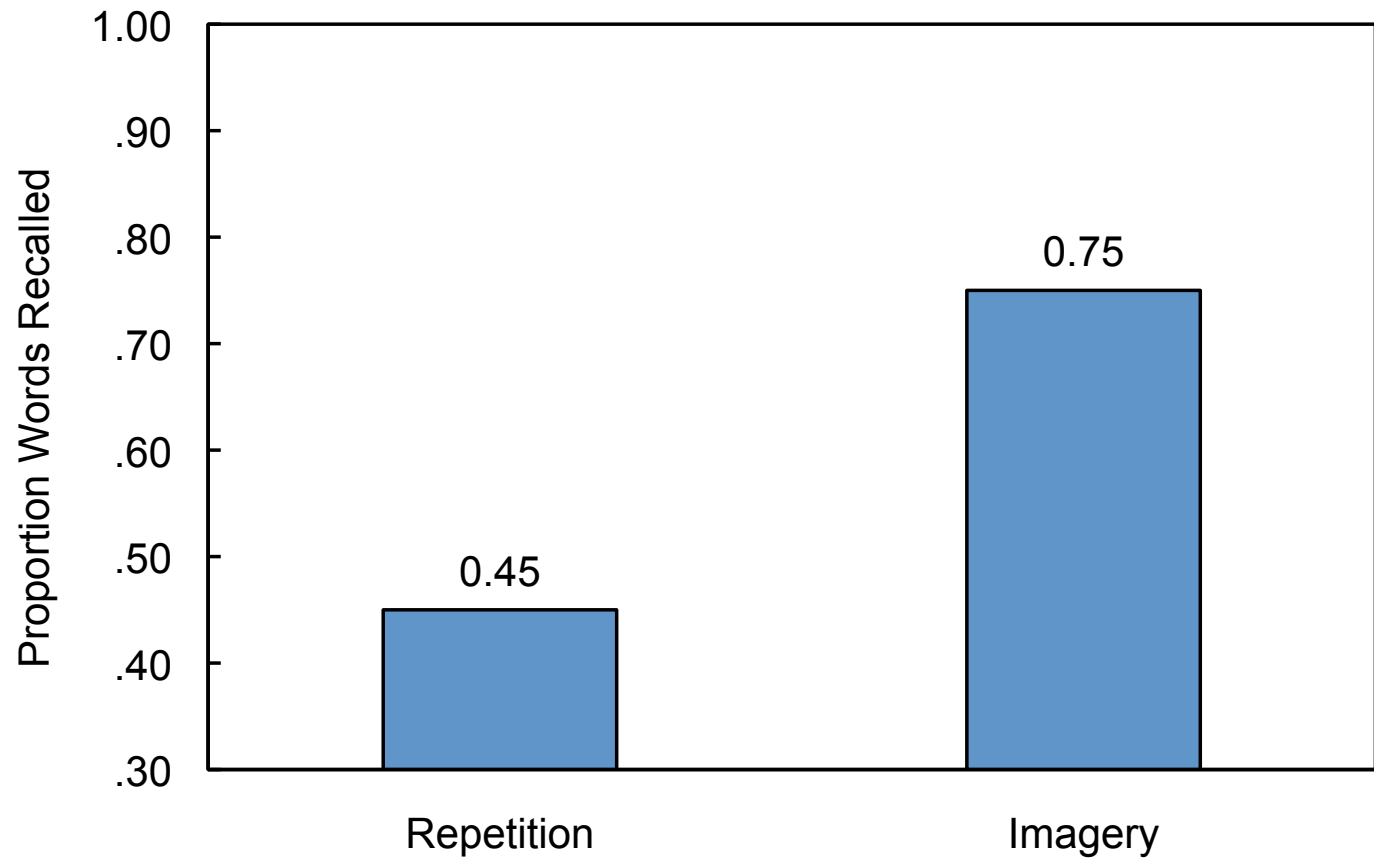


- Test: Recall as many words as possible



Power of Imagery

- Students studied 100 pairs of words
thumbtack - pickle
- Two conditions:
 - Repetition or rehearsal: silently repeat words until the next pair occurs
 - Mental imagery: form images of the two words and have the images interact
- Test: Left word provided, recall other word
thumbtack - ????



Interim Summary

- Recoding is one key to successful memorization
- Imagery represents one effective recoding technique for verbal materials
- Retrieval is critical, too

- Classic mnemonic devices (strategies for improving memory) supply both good recoding strategies and retrieval cues
- Method of loci:
 - Identify a set of discrete, well known locations
 - Place images of items to be remembered in each location

Prior studies provided only one opportunity to learn

The typical experiments on learning offer more than one opportunity: Multiple learning and testing trials

What leads to learning?

WHAT LEADS TO LEARNING?

reading
lectures
studying
reviewing

HOW DO WE MEASURE LEARNING?

quizzes
tests
exams

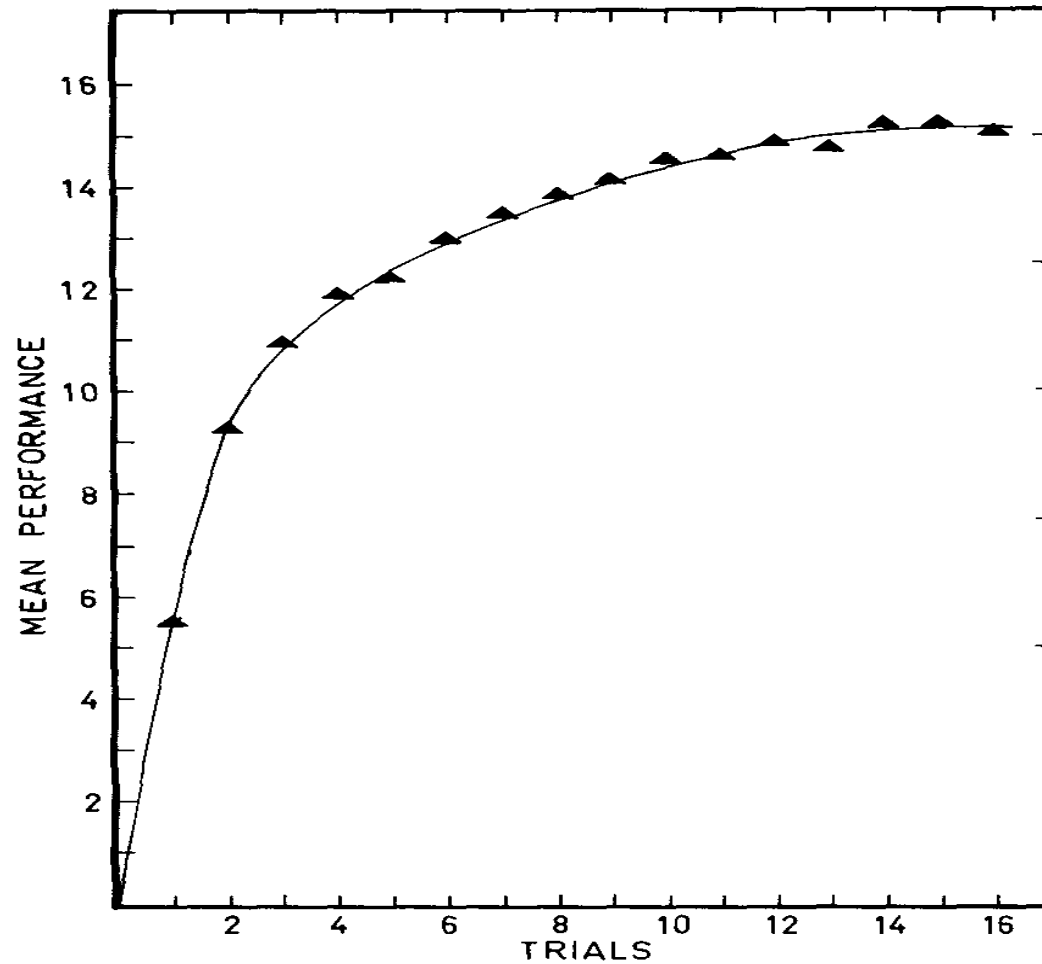
Learning experiments

- Study material (S)
- Test on it (T)

ST ST ST ...

A LEARNING EXPERIMENT

16 words
16 ST trials
Free recall



Tulving (1962)

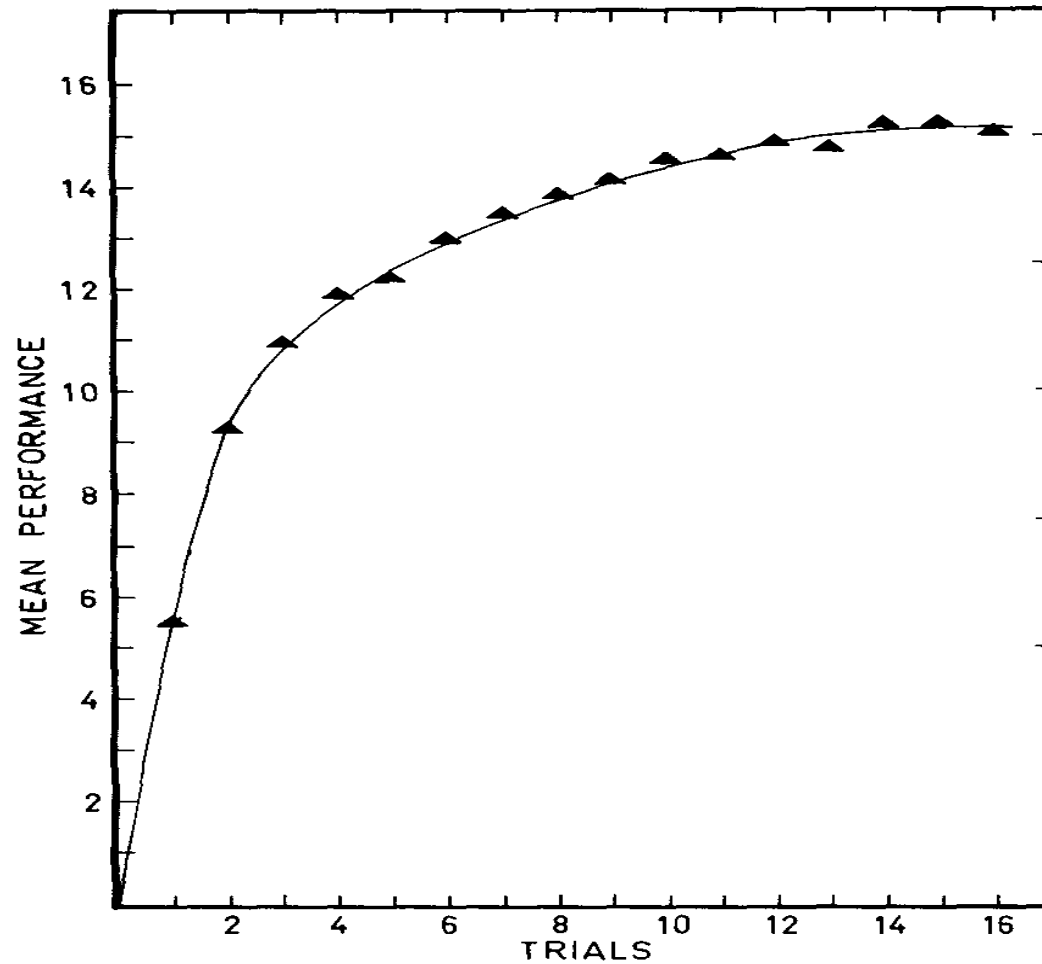
A CENTRAL QUESTION IN 20th CENTURY PSYCHOLOGY:

Why does learning occur?

**A great debate raged 50 years
ago: gradual vs. all-or-none
learning**

A LEARNING EXPERIMENT

16 words
16 ST trials
Free recall



Tulving (1962)

FUNDAMENTAL ASSUMPTIONS

Study episodes elicit learning.

Study - Test Study - Test Study - Test . . .

Tests are merely assessment tools; they *measure* what students have learned during study periods.

Are these assumptions correct?

To find out: Manipulate the number of study and test opportunities

50-word list	Birds	cardinal
10 categories		sparrow
5 items/category		pigeon
		bluejay
		robin

ST ST ST ST 4 study, 4 test

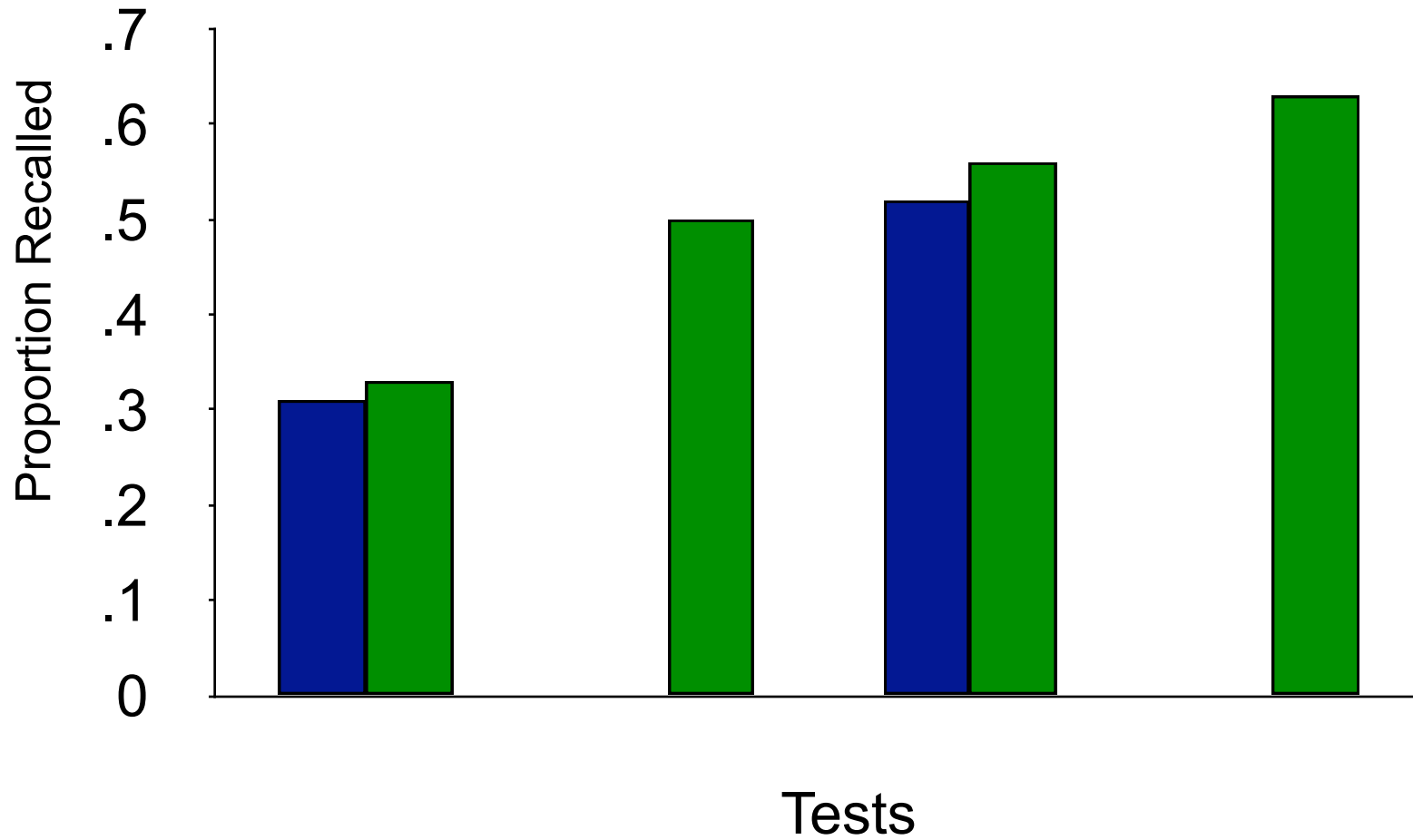
ST SS ST SS 6 study, 2 test

SS SS SS SS 8 study, 0 test

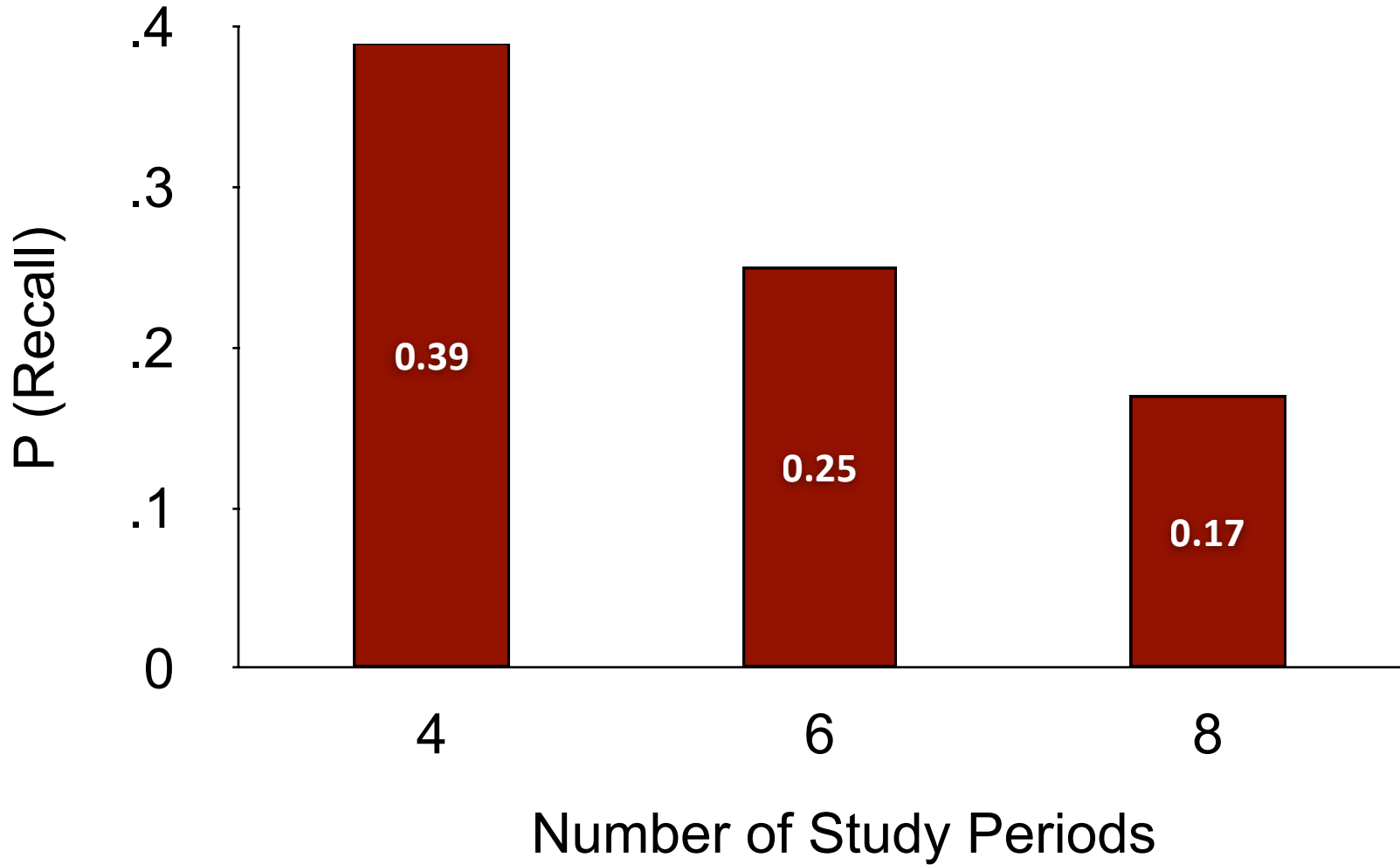
Final test 48 hours later

- 2-Test (ST SS ST SS)
- 4-Test (ST ST ST ST)

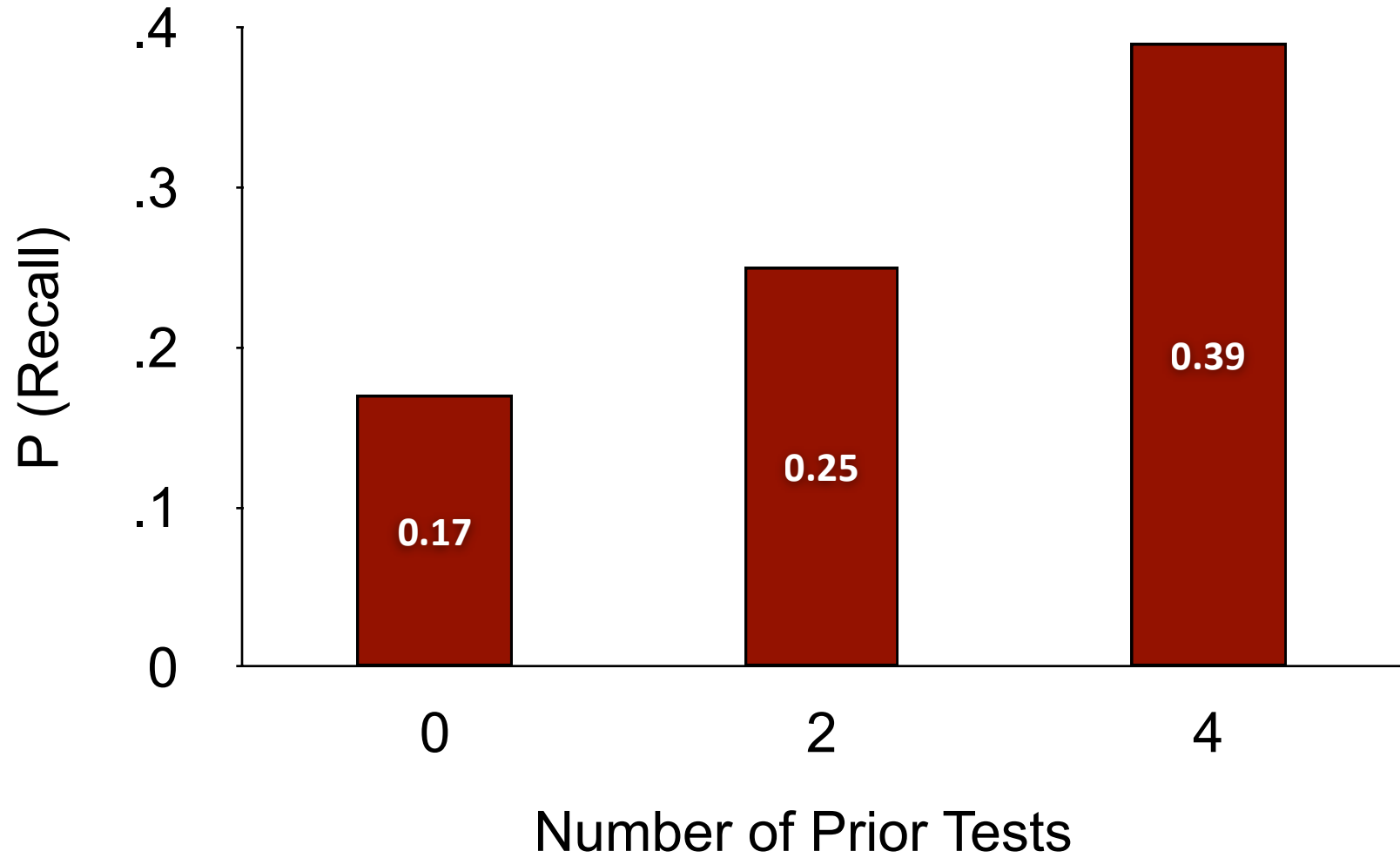
LEARNING PHASE



48 HOURS LATER



48 HOURS LATER



THE TESTING EFFECT

Testing of memory not only assesses what we know, but changes it.

Many studies show that testing can enhance later performance more than additional study.

Roediger & Karpicke (*Perspectives on Psychological Science*, 2006)

CAN WE MAKE LEARNING MORE EFFICIENT?

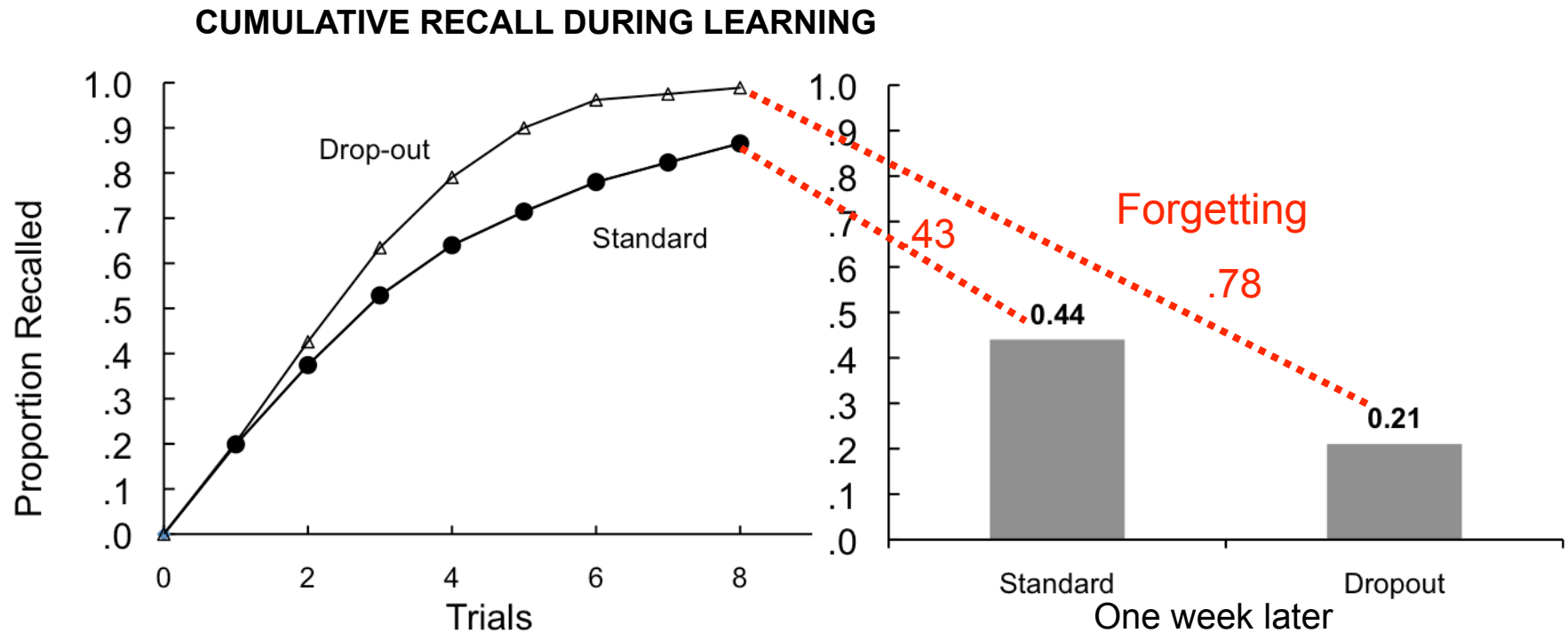
Standard condition seems inefficient, with repeated studying and testing of events that have already been learned.

Develop a drop-out condition: Once a word has been retrieved, drop it from study

40 words / 8 trials, and then a final test one week later.

Like the advice given for use of flash cards.

DURING LEARNING, THE DROPOUT CONDITION SEEMS TO WORK BETTER



Faster learning, higher total performance.
Students are perfect by the end.

DESIRABLE DIFFICULTIES

Often conditions that make learning slower and more difficult enhance later retention.

What is it about the standard (study/test) condition that fosters better retention?

- Increased study opportunities?
- Increased test (retrieval) opportunities?
- Or both?

Paired-associate learning; 4 trials

40 Swahili-English word pairs

Study: *mashua – boat* *lesa - scarf*

Test: *mashua – ???* *lesa - ???*

Use all 4 conditions

Study all, test all

ST ST

Study all, test nonrecalled

ST ST_N

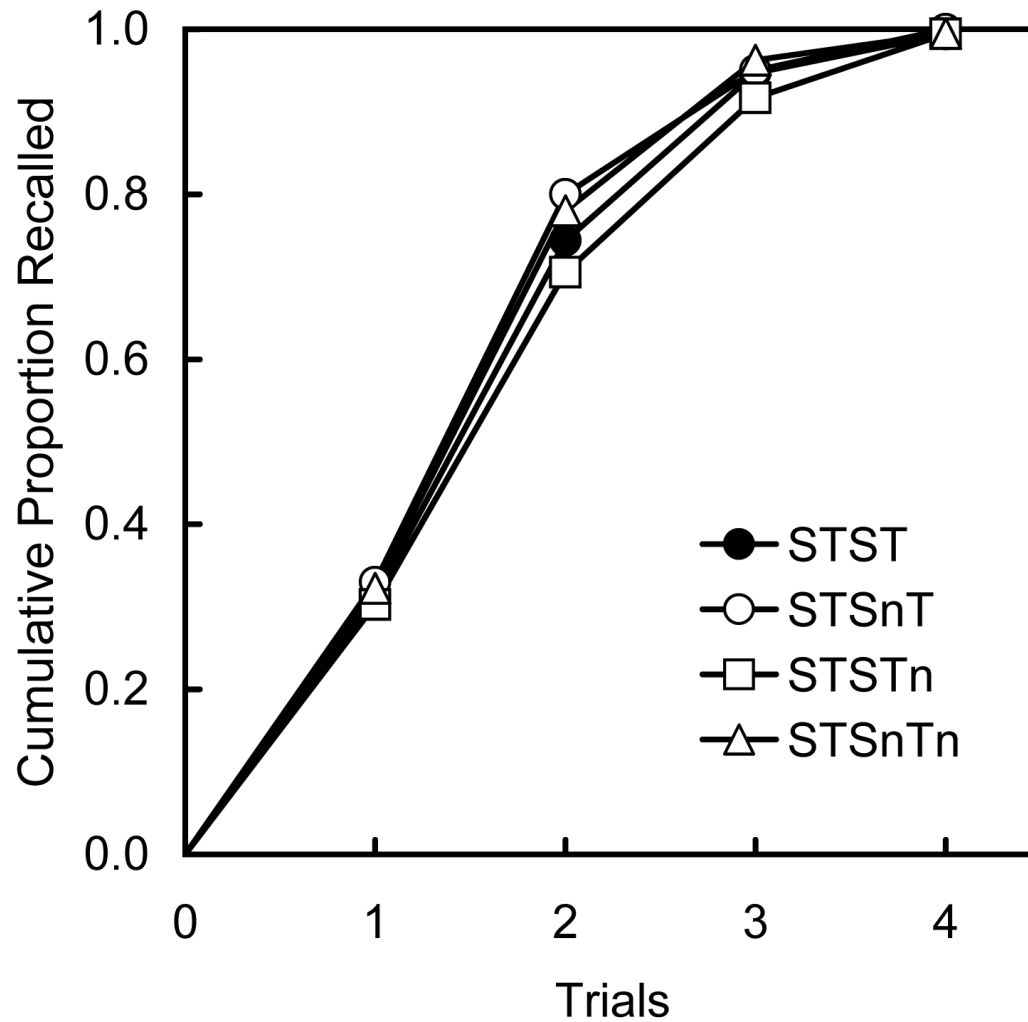
Study nonrecalled, test all

ST S_NT

Study nonrecalled, test nonrecalled

ST S_NT_N

LEARNING PHASE



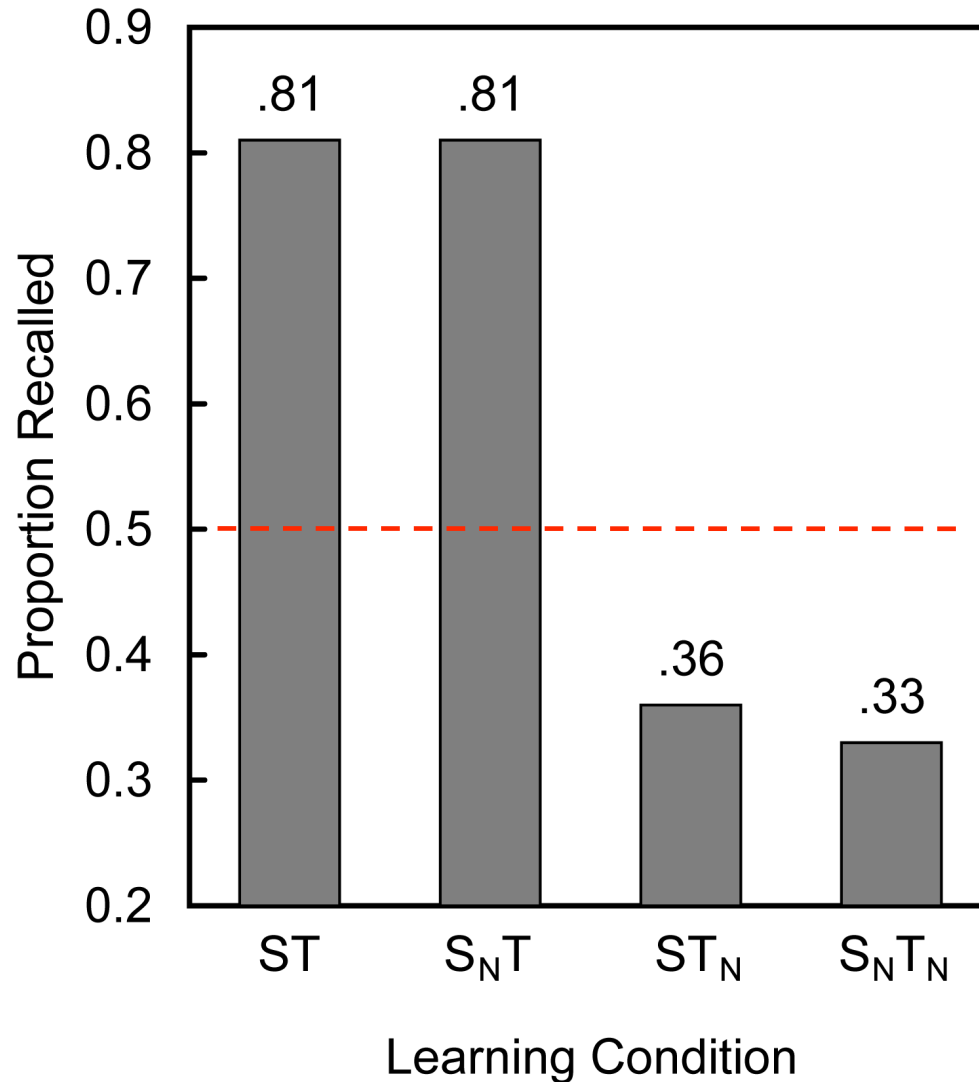
Karpicke & Roediger (*Science*, 2008)

STUDENT PREDICTIONS

“How many words will you recall in 1 week?”

All conditions = ~ 50% (no differences)

ONE WEEK LATER



Repeated studying after learning had no effect on delayed recall, but repeated testing produced a large positive effect.

INTERIM CONCLUSIONS

Repeated retrieval is the key to long-term retention.

Beyond some minimal amount, repeated studying does not much matter.

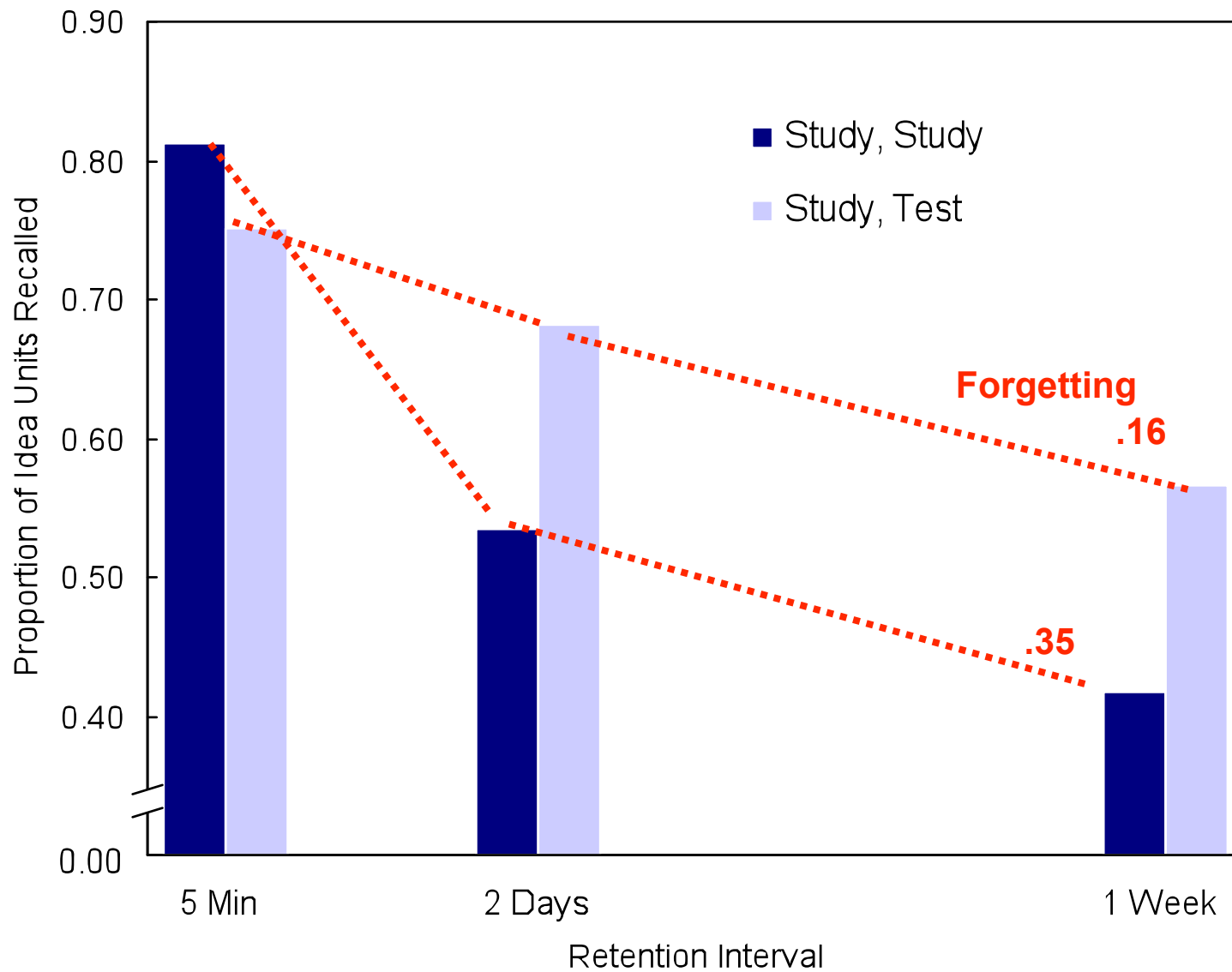
Testing of memory not only assesses what we know, but changes it. The benefits can be great.

DOES TESTING REPRESENT A DESIRABLE DIFFICULTY WITH PROSE MATERIALS THAT ARE MORE RELEVANT TO EDUCATION?

Study prose passages

Then restudy or test (free recall, no feedback)

Final test: 5 min, 2 days, or 1 week



Roediger & Karpicke (2006)

Summary

Testing effect does generalize to educational materials (passages).

Repeated reading leads to short-term boost, but testing enhances long-term retention.

Subjective experience (prediction of future recall) is inflated by repeated studying.

Feedback enhances the testing effect.

Effortful retrieval produces the greatest effects.

TRANSFER-APPROPRIATE PROCESSING

Memory performance benefits to the extent that operations performed during learning are reinstated on a later test.

When students engage in retrieval practice during learning, they practice the same skill needed to retrieve later.

Potentially useful theory for educators, although it seems little used.

Does testing simply produce rote learning
(as in “teaching to the test”)?

Does testing produce learning that transfers
or generalizes to other forms of test?

McDaniel, Howard & Einstein (2009)

Butler (2009)

Study passages, then repeatedly re-study or test
Final transfer test (48 hours)

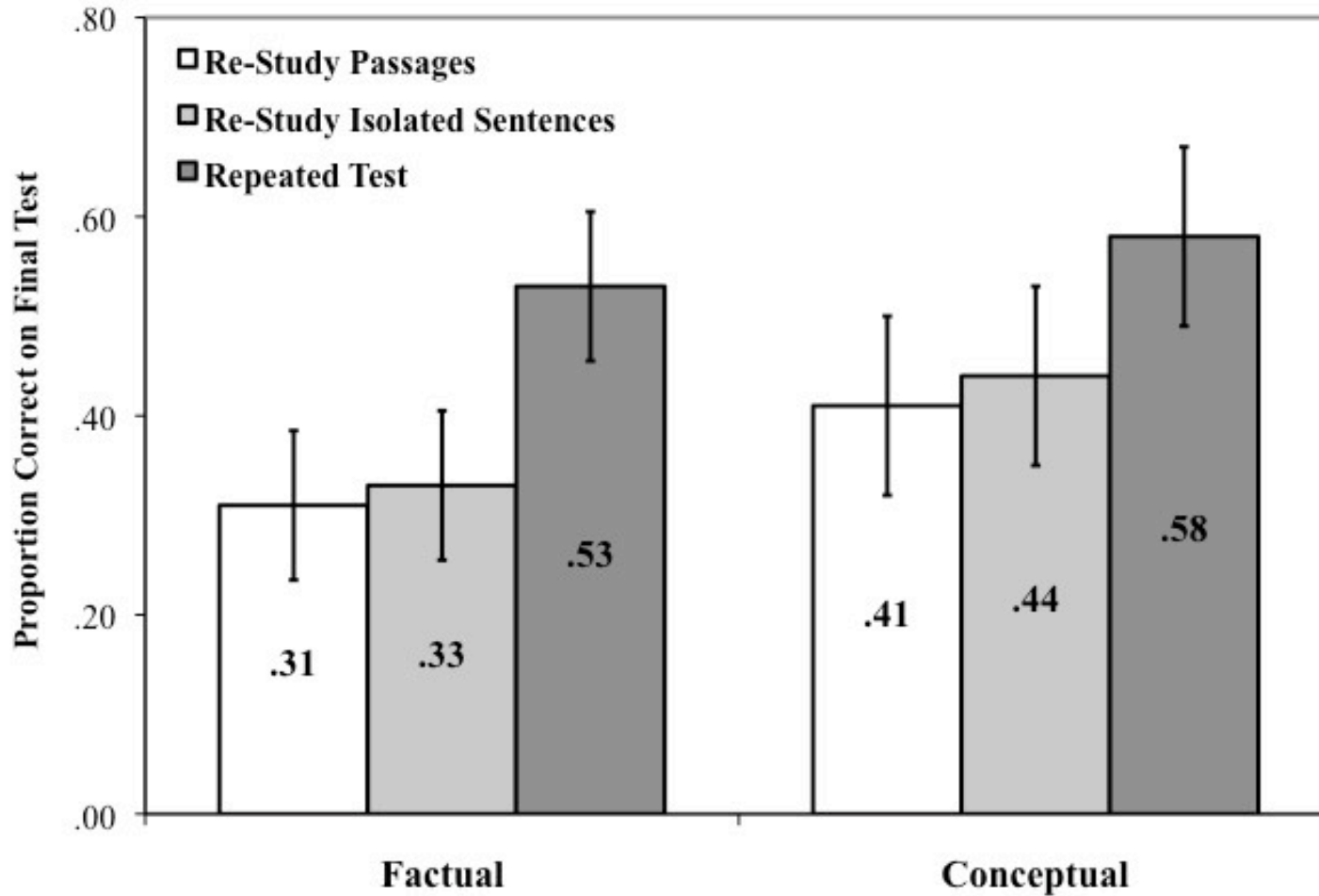
Prose passages that contain facts and concepts
Initial test questions about facts and concepts
Transfer test questions that require inference

Re-Study Passages	S S S S	Final transfer test
Re-Study Sentences	S S S S	Final transfer test
Repeated Test	S T T T	Final transfer test

Feedback was given after every test question.

Butler (2009)

Final Transfer Test



Butler (2009)

WHY ADVOCATE TESTING?

Testing enhances learning: Students engage in retrieval processes, practicing the skill needed to access information in the long term.

Testing has both direct and indirect effects.

Indirect effect: Increased studying.

DOES TEST-ENHANCED LEARNING WORK IN REAL CLASSROOMS?

Columbia Middle School project

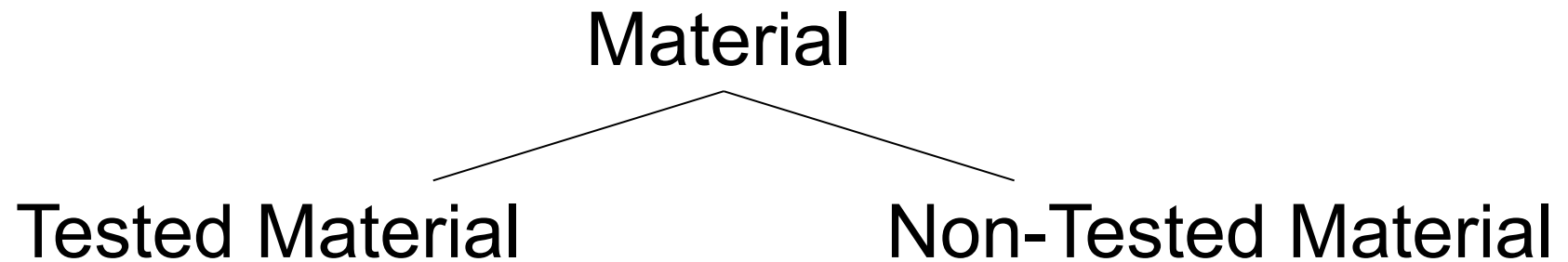
6th, 7th, and 8th grade science classes

Some facts on each lesson are quizzed 3 times; comparable facts are not quizzed

Consider recall on tests at ends of chapters, end of the semester and end of the year

Mark McDaniel, Kathleen McDermott and Pooja Agarwal

Within-Students Design



Which type of material is easier to remember on a final test?

Initial Quiz Performance

Pre-Test
43%



Class Lecture



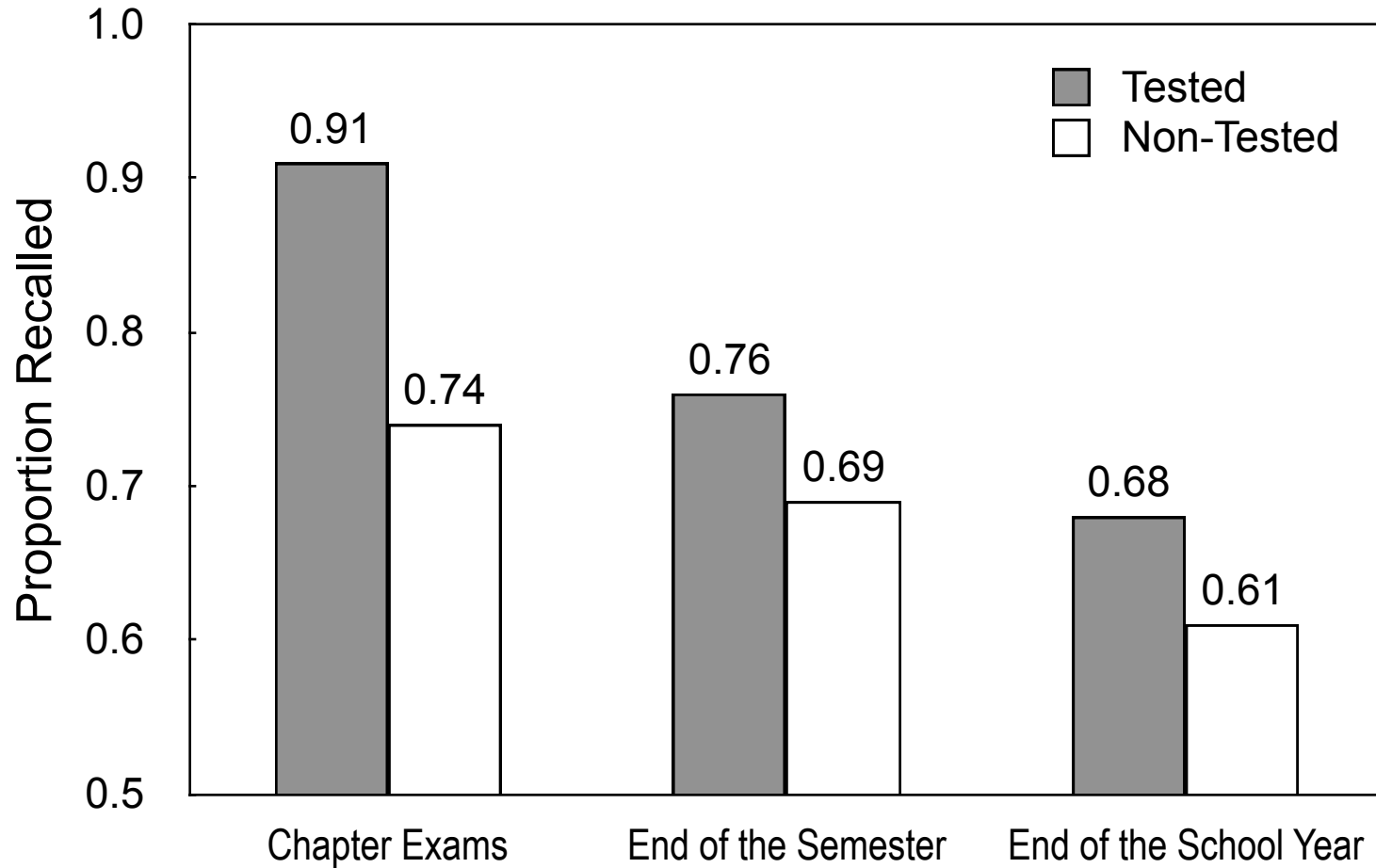
Post-Test
91%



Review Test
91%

COLUMBIA MIDDLE SCHOOL PROJECT

8TH GRADE SCIENCE



CONCLUSIONS

Repeated retrieval is the key to long-term retention

This research represents a new way to look at the learning process – retrieving can enhance retention more than studying

Effortful retrieval and feedback on tests are critical

Important educational implications flow from the power of testing or repeated retrieval as a mnemonic technique.

Self-testing should be incorporated into students' study strategies.

**“Exercise in repeatedly recalling a thing
strengthens the memory”**

Aristotle, *De Memoria et Reminiscentia*

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